A Handbook of Modern Practice for the Craftsman, Tradesman & Engineer

VOLUME TWO

THE ENCYCLOPEDIA OF SANITARY E HEATING &

A Handbook of Modern Practice for the Craftsman, Tradesman & Engineer

SANITARY & DOMESTIC ENGINEERING · HOUSE & GENERAL PLUMBING · FITTINGS & FITMENTS · LEAD & LEADWORK · IRON & STEEL · COPPER, BRASS & OTHER METALS & ALLOYS · ROOFWORK · PIPES & PIPEWORK · JOINTS · WELDING, BRAZING & SOLDERING · HEATING & HOT WATER SYSTEMS · VENTILATION · GAS & ELECTRIC FITTING & SUPPLIES · DRAINS, DRAINAGE & SEWERAGE · WATER & WATER SUPPLIES · ACCOUNTING, QUANTITIES, ESTIMATING · LAWS & BY-LAWS · SCIENCE FOR STUDENT, CRAFTSMAN & ENGINEER

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PRINCIPAL ARTICLES VOLUME 2

PRINCIPAL ARTICLES (continued)

LIST OF PLATES IN VOLUME 2

IDEALS IN MODERN DRAINAGE. WORK

Notes on the Progress made in Plumbing and Sanitary Engineering

By Frederick C. Cook, M.R.San.I., M.S.I.A., R.P.
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SANITATION in this country has made great advance during the past 100 years, while the standard of sanitary construction compatible with hygienic principles was left to the inventive genius of sanitarians of comparatively modern times.

One could quote amongst others, Chadwick, Hellyer, and Clarke, who devoted their lives energies to the advancement of sanitary science, and succeeded in revolutionizing the insanitary conditions which prevailed in their time, forming basic principles on which evolutionary progress has provided the sanitary amenities prevalent in our homes today.

The town dweller has simply to turn on a tap, lift a plug, or discharge a flushing cistern, and he can be assured that the discharge from the fitments are being dealt with in an hygienic manner.

Drainage Old and Modern

IN dealing with modern drainage work, which includes the installed fitments, together with the piping necessary to carry their discharges to the sewer, it is well to reflect on past sanitation to appreciate present day conveniences.

Omitting to record details of the crudity in sanitation of past generations, when drainage consisted of an open water course, one finds that the first drains were constructed of brick, which formed a rectangular closed channel, followed at a later date by earthenware pipes with shallow sockets for which clay was used to form the joints.

In 1845, glazed stoneware pipes were first used, and with a deeper socket, the joint being made with cement. A similar pipe is in general use today.

Iron drains were first introduced in the 1880s, to enable drains to be laid under buildings. In the absence of acid discharge, iron drains are undoubtedly the most suitable, and are essential where construction conditions call for them to be suspended from the ceiling, or supported by wall cantilevers.

In the London area, where buildings of 8 to 10 floors are above ground, and 2 or 3 floors below ground, special consideration is necessary in devising the drainage system, due to the sub-basement floor being well below the town sewer, which requires some of the sewage to be conserved for a time, and liberated by pump action.

Water Closets over 160 Years

A NUMBER of attempts were made to produce a serviceable water closet to supersede the privy, which was virtually an open cesspool, and frequently situated within the house. In 1790, the "pan and container" was introduced, which with improvement to its flushing apparatus found favour for many years. I had one removed as recently as 1930.

This type was followed by the valve closet, many of which in modernized form are in use today. Hellyer did much to perfect this form of water closet.

Various types were in vogue for a time, such "plug closet," "wash-out," "long hoppe ' all of which are now prohibited on the ground of being not self-cleansing.

The present types are pedestal and siphonic. The former has found favour for many years, and has proved itself to be an hygienic fitment. The latter is considered to be the acme of perfection.

Water Supply For Closets

WE in Britain are very conservative with our water supply to closets, allowing only 2 gall. for flushing purposes, which has to carry waste matter through the drains to the outgo, irrespective of its length. The U.S.A. provide a minimum of 4 gall., and permit the use of an automatic flushing valve in lieu of a flushing cistern, which is prohibited in the London area.

The early flushing apparatus to closets consisted of a rubber seated lead drop valve, fitted to the head of a 1 in. dia. flush pipe, situated within the drinking water cistern. The main water supply to the cistern usually functioned for 1 hour per day under the then intermittent system of water supply.

When separate flushing cisterns were first introduced a similar drop valve was installed, which permitted a waste of water when the seating of the valve was defective. This type is now prohibited by the Water Board, and a valve-less type substituted.

From an appearance point of view the "low-down suite," consisting of a pedestal closet and a porcelain flushing cistern to match, both in design and colour, and fixed immediately above the closet, is finding favour, and largely used for high-class flats.

The Modern Baths, Basins and Sinks

GONE are the days when one took one's daily ablution in a hip bath, placed on the bedroom floor, which required filling and emptying by hand.

The early cast iron bath was coated with enamel, and stoved; *i.e.* baked to harden the enamel, necessitating periodic renovation. The present day bath has a permanent glazed face, which is formed by powdered glass applied to the surface while the bath is in a white-hot condition.

Some modern baths are constructed in one piece which includes the front panel and one end panel, while the water is supplied by means of a mixing valve, and emitted through one orifice; with a shower attachment, and all chromium plated fittings, the fitment is an object of beauty.

Independent shower baths found favour in high-class flats prior to the last war, and I have wondered why they are not more frequently used, particularly for artisans' dwellings, seeing that they effect economy not only in the use of hot water but also in floor space.

The feature of the early wash-bowl was the mahogany cabinet which invariably surrounded it, giving support to the bowl and concealing the waste water container, which required emptying by hand, the water being supplied from a metal water can.

The modern basin, with its weir overflow, cast in shelf supported by a chromium plated towel-rail stand, together with fittings and other accessories, forms a feature of the bathroom. The installation of a basin in the bedroom is an acquisition which adds greatly to the amenity of that apartment, particularly if it is a family flat or house.

The shallow york stone sink, fitted with a loose metal bell trap with the base cemented to an earthenware pipe and connected to the house drain, has long given way to the glazed fireclay deep sink with its self-contained overflow. One rarely sees the leadlined butler's pantry sink, which at one time was very popular in large houses. A more recent innovation is the stainless steel sink which, with its " draining boards " of similar metal and set within a cabinet, forms a treasured possession of any housewife.

Vertical Soil and Waste Pipes

THE most popular metal used for these purposes is coated cast iron. The introduction of a recess in the top astragal of the socket now renders it impossible for the well-caulked lead forming the joint to " creep," which was possible without the recess, particularly when warm water passed down the pipe.

Copper was frequently used for main stacks prior to the Second World War, and provides a first-class job. Its post-war cost usually renders it prohibitive.

I was associated with one building which contained some 850 bathrooms, with the plumbing work constructed entirely of copper pipe, using half-inch dia. services to some of the fitments, up to 4 inch dia. for soil and waste pipes. From inquiries made, I learnt that no trouble had been experienced during the 13 years of constant use.

The One-pipe System (Combined Soil and Waste Pipe)

IN modern buildings, whether they are flats, offices, hotels, or business premises, the vertical drainage is invariably carried out on the one-pipe system, *i.e.* one main waste pipe which may or may not receive the discharges from soil fitments. The waste pipe discharges direct to the drain without the interposition of a gully trap. From a hygienic point of view,

the omission of the gully trap is in my opinion its principal virtue.

In the London area, prior to 1934, the year of By-law sanction of "One-pipe," all soil and waste pipes were kept separate; soil discharging direct to the drain, waste pipe discharging into a gully trap. During that period a number of high-class flats were constructed which when occupied set the perplexing problem of how to obviate the nuisance which arose due to soap-suds flooding a large area around the gully. By sealing the gully, the soap-suds would mount up within the main waste pipe, while the next discharge from the upper floors would force them through the lower branch waste pipe trap into the fitment to which it was attached. The cause of the trouble was due to the wasteful usage of soap powders by the tenants on the upper floors, which caused the soap-laden discharges to break up into foam during its long drop to the gully.

Against the Foul-Water Gully

To obviate this condition, the gully was sealed to prevent surface flooding, and the fitments on the two lower floors were discharged into a separate waste pipe, while the anti-siphonage pipes were connected to the main A.S.P. on the 3rd floor. This condition cannot arise when the one-pipe system is installed seeing that no gully is installed (other than R.W. gullies) and the discharges go direct to the drain.

I cannot speak too strongly in discouraging the use of the foul water gully where possible; one has only to examine one's own house gully to appreciate the insanitary condition which arises from incrustation of soap and other fats, together with general filth, which decompose and permeate the surrounding atmosphere with foul gases.

Economy is another factor in favour of the system, particularly when used on tall buildings, seeing that only two vertical stacks are required as against four stacks under the older system.

Advantages of Plumbing Ducts

The days when one admired well planned and neatly executed plumbing work displayed on the external wall are over, which reminds me of a famous New Yorker who, when visiting this country some years ago, was asked for his first impression, and asserted that he had not seen so many petrified worms decorating buildings before!

The trend of modern architecture is to house the entire plumbing work within the building. To do this, it is necessary to give up floor space to form a plumbing duct, which invariably is inadequate, particularly if repairs or alterations have to be made. I was interested in one large hotel where adequate space was provided; it measured 8 ft. by 3 ft. extending vertically for eight floors; in addition to all plumbing services, other trade services were included. There were 56 such plumbing ducts in the building.

Internal Sanitary Apartments

London architects have taken advantage of the provisions of the L.C.C. Closet By-laws passed in 1930, to install internal water closets, usually in conjunction with bath, lavatory basin and sometimes with a bidet, thereby gaining larger and lighter living rooms abutting the external wall. This installation is made possible by installing mechanical ventilation and artificial lighting; and is very adaptable in modern flats and hotels, where a water-closet apartment repeats itself on successive floors. This provision is also made in the M. of H. Model By-laws (now 19 of Local Government).

Another welcome innovation is that the closet apartment can be entered directly from a bedroom, provided it is used exclusively by the occupants of the bedroom. Previously one had to construct a separate closet apartment, approached from the corridor or within the bathroom, and comply with closet regulations deeming the bathroom as the ventilated lobby.

The arrangement is very acceptable not only for large houses with "best" bedroom, but also for conversion of such houses into two or three room flatlets.

Modern Flats

Much consideration has been given to high-class family flats during the last 25 years, which render them more desirable than the earlier town house, due

possibly to economy, or servant problems. Not only is the residential comfort of the occupier considered, but also the social side is well conceived, which include restaurant, garage, guest rooms, and a host of other amenities.

Progress has also been made regarding the comfort and well-being of occupiers of artisans' dwellings, particularly in the culinary department, consisting of a deep glazed sink and drainage boards, hinged table, electric cooker, refrigerator, food cupboard, shut-in ironing board, and cupboards to fill the kitchen wall space. All flats are provided with a bathroom, containing a lavatory basin, and usually a constant supply of hot water. Provision is made for use of a communal laundry.

An old block of artisans' dwellings, part of which was destroyed by enemy action, came under my supervision, necessitating the reconstruction of the centre of the block, consisting of four two-bedroom flats on each of the five floors. The problem of installing bathrooms in the restricted space was ingeniously solved by grouping the four bathrooms around a well-hole in the centre of the block (about 12 ft. by 3 ft.) with two bathrooms on opposite sides of the well-hole; there being an existing staircase within the block at either end.

Owing to the bathrooms being internal and containing a water closet, mechanical ventilation and artificial lighting was installed, and was, I think, the first installation for artisans' dwellings.

Single Pipe (Simplified One-pipe)

DURING the war years experiments were carried out on full scale plumbing installations suitable for 2-storey houses, to ascertain the suitable diameter and length of pipes which would function satisfactorily from a non-siphonage point of view without installing anti-siphonage pipes. The result of these tests is tabulated in a comprehensive Chart which can be found in the appropriate section in Volume 3.

Although one appreciates the value of ventilation in drainage systems, there is no logical reason to install needlessly ventilation pipes which can be omitted without loss of efficiency to the system. The shortage, and cost, of metal pipes render it very necessary for legislation, with proper reservations to be enacted, permitting the use of the system. The L.C.C. Drainage By-laws being under revision (1951) there was every possibility that the system would be included.

House Refuse Disposal—Garchey System

HOUSE refuse storage, collection, and disposal as at present practised, is far from satisfactory, and relies far too much on the human element for its hygienic success.

With the Garchey system, once the refuse, consisting of ashes, waste vegetable matter, tins, etc., are deposited through the aperture in the bottom of the sink, and the plug released in the container below the sink, the human element takes no further part in its disposal, apart from the engineer at the disposal station, who actuates a number of valves. Details of the system are dealt with under Refuse Disposal in Vol. 3.

The system is very suitable when a number of blocks of flats are grouped. The initial cost of the installation is high, but the advantages are many.

Conclusion

ONE of the trials of a student studying a technological subject is that not only must he obtain text books dealing with the subject in its various aspects, but must also acquire legal knowledge of the subject, necessitating the purchase of appropriate Acts, by-laws, and regulations.

In my opinion, the student taking up any of the subjects contained in the three volumes of this Encyclopedia will find within the covers all the necessary information for him to master the subject selected. Throughout my student days, I found that illustrations are not only helpful in grasping the subject discussed, but have a lasting value, imprinted on the mind of the observer. One of the principal features of the Encyclopedia is, in my judgment, its illustrations.

To others who have an interest in the subjects discussed, be they architects, surveyors, sanitary administrators or mechanics, they will find the volumes invaluable as up-to-date reference books.

THE ENCYCLOPEDIA OF SANITARY ENGINEERING, HEATING & PLUMBING

A Handbook of Modern Practice for the Craftsman, Tradesman and Engineer

VOLUME TWO

FANS. Fans are mechanical devices for moving air. They may be divided into two general types—propellor and centrifugal. A propellor fan is similar to a screw propellor, and moves air in a direction parallel to its spindle axis. It acts by increasing the air velocity, and produces very little or no pressure. Modifications of the propellor fan of which this is not strictly true are described below. With a centrifugal fan the air flows in parallel to the spindle and is discharged at right angles to it.

Definitions

Impellor. That part of the fan which revolves and is the actual means of moving the air. Sometimes known as the runner or wheel.

Casing or ***Housing.*** A casing usually of sheet steel, enclosing the impellor. It carries the "suction," through which air flows to the impellor; and the "discharge," through which air flows from the fan. Often the casing has a bearing fixed to it which supports the spindle.

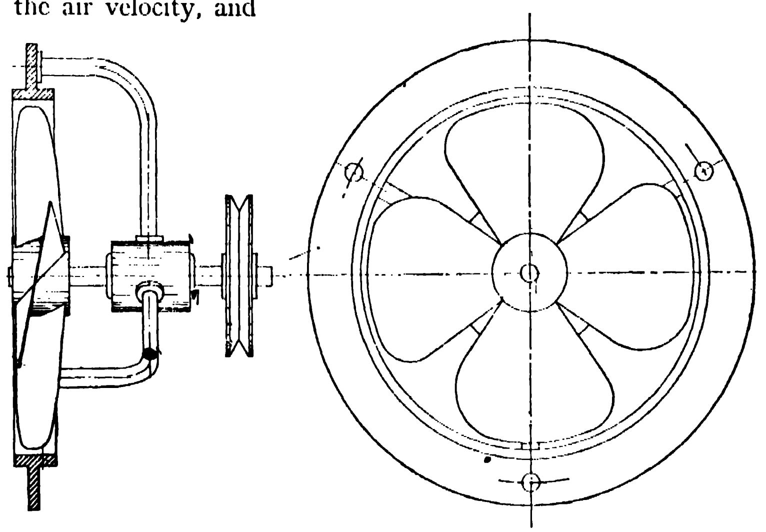
Tip Speed. Speed of the outer edge of the impellor when fan is running. Calculated from formula

$$T.S. = R.P.M. \times D \times 3{\cdot}1416$$

where T.S. is tip speed of impellor in feet per minute, R.P.M. is revolutions per minute of impellor and D is diameter of impellor in feet.

PROPELLOR FANS

These (Fig. 1) consist of a circular hub on which are fastened a number of blades, the whole forming the impellor. The number of blades differs with varying makers, and with diameter of impellor. There may be three blades, or as many as twenty-four. The blades may be flat sheets of metal, or they may be curved. The impellor is set-screwed and keyed to



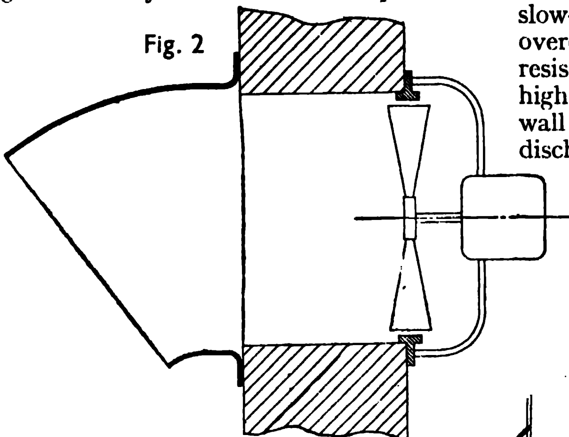
FANS: Fig. 1. Side and front view of propellor fan, which moves air in a direction parallel to its spindle axis and increases velocity with little or no pressure increase.

the spindle. When the fan is belt driven the spindle is carried in a bearing which may be of the ball type, or may be a plain bearing with ring oiling. The bearing supports and secures the impellor. The bearing itself is secured in a housing from which two, three, or four arms run to the fan ring. The ring is the means of fastening the fan in position, and the impellor revolves in it. Often the impellor is carried on the extended spindle of a motor, doing away with the need for a separate bearing. In this case the motor is carried by arms from the fan ring.

Manufacturers list propellor fans according to the diameter of the impellor. The delivery of the air in cu. ft. per minute for

each size is given, often at two or three speeds. When this is so the lowest speed will be used in places where quiet running is essential—as for instance churches. The highest speed will apply to buildings, like factories, where noise is immaterial. If an intermediate speed is given it may be used in such places as

Fig. 2



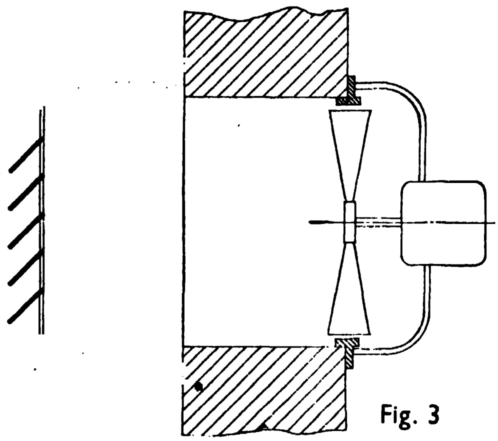


Fig. 3

FANS. Figs. 2 and 3. Two methods of protecting slow-running propellor fan discharge from outside draughts: (above), cowl; (right), outside louvres which may be fixed, or may be pivoted to act as automatic shutters.

shops, where complete quiet is not required.

Fan Capacity and Speed. If a fan maker's list of propellor fans is consulted it will be found that the duties are for free air conditions. This means that the fan has no air duct attached to it or other resistance to flow. Fans are usually fixed direct to the wall of a room so that they blow air either straight from the room to atmosphere or vice versa. In such circumstances the required fan capacity is easily found. Normally the ventilation requirements are specified as a given number of air changes per hour. Multiplying the number by the room volume will give the fan capacity in cu. ft. per hour. On dividing by 60 the required delivery in c.f.m. (cu. ft. per minute) is obtained.

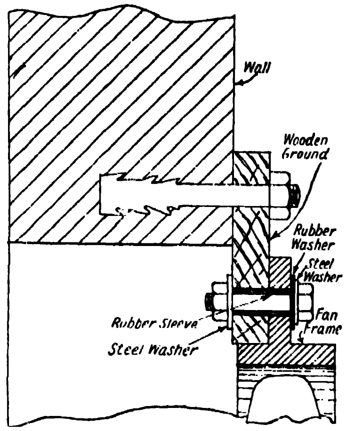
A fan for this delivery may then be chosen. If it is direct coupled to the motor and the electrical supply is A.C. it must run at a suitable speed. Possible speeds on a 50-cycle supply are 3,000, 1,500, 1,000, 750, 600, 500, etc. (Theoretical possible speeds are obtained by dividing 3,000 by any whole number. Actual speeds are about 5 per cent. lower.) Having chosen the fan, its tip speed should be checked. If quiet running is desired this should not exceed 3,500 ft. per min. If the desired delivery is not listed, choose the nearest one and adjust the speed to give the proper delivery by means of the fan laws printed at the end of this article.

Discharge Arrangements. Since a slow-running propellor fan is unable to overcome any but the very smallest resistance, it must be protected from high winds. If it is fixed on an exposed wall subject to direct winds it must not discharge straight into the wind. Two methods of arranging the discharge are shown in Figs. 2 and 3. The first consists of a simple bend looking down, and the second of a box with louvres on the outside. The diameter of either should be not less than one and a half times the diameter of the fan, to ensure no reduction of duty.

Where a propellor fan is exhausting direct from a room to atmosphere, draughts are often encountered when the fan is not in use. It will be found that quite light winds blow straight through the fan into the room, which is particularly unpleasant in cold weather. To avoid this, automatic shutters should be fixed on the discharge side of the fan. There are several types, but one of the simplest is similar to Fig. 3. The louvres, instead of being fixed, are pivoted and made of aluminium. They are very narrow, so that a very small pressure will open them. When the fan is not running they close by their own weight and, since they overlap, they form a complete barrier to reversal of air flow. They reduce the air

delivery slightly, and a small margin must be added to the calculated quantity to allow for this.

Motors. The motors usually fitted to propellor fans are of the enclosed ventilated type. These are quite satisfactory when the fan is handling normal room air. If, however, the air flowing through it contains corrosive fumes, steam, or a large amount of dust, a totally enclosed motor must be used. The fan also may need to be of special material. In all cases it must be remembered that the motor bearings require oiling, and must be accessible for that purpose. When the fan is fixed in a duct an inspection opening and cover should be provided to allow of lubrication.



FANS. Fig. 4. Mounting for propellor fan to avoid vibration: fan separated from wall by hardwood ground, and from latter by rubber washers under bolt head and rubber sleeve on stem.

The fan ring has bolt holes cast in it by which the fan may be bolted to a wall. The hole in the wall should conform in shape and dimensions to the fan ring. For silent running the fan should be insulated from the wall, as illustrated in Fig. 4. The fan is bolted to a hardwood board not less than 1¼ in. thick. The bolts are surrounded by rubber sleeves, and rubber and steel washers are used under the nut and bolt head. In this way the metal of the fan makes no contact with the wood, which is in turn bolted to the wall.

Sometimes propellor fans are used to extract vitiated air from small halls, small cinemas, etc. Gratings are fixed in the ceilings, allowing air to pass from the hall to the roof space. A propellor fan fixed in the end wall then extracts the air from the roof space. This is quite satisfactory provided the grating area is large enough to allow a low air speed through it. The speed should not exceed about 200 feet per minute, and the fan if chosen from a list of free air duties should have about 20 per cent. margin. The general arrangement is shown in Fig. 5.

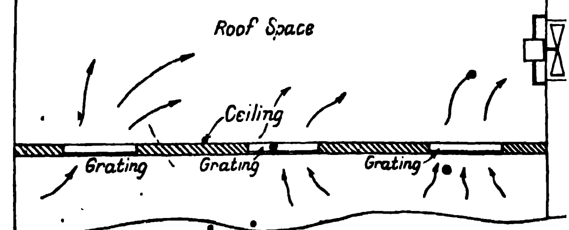


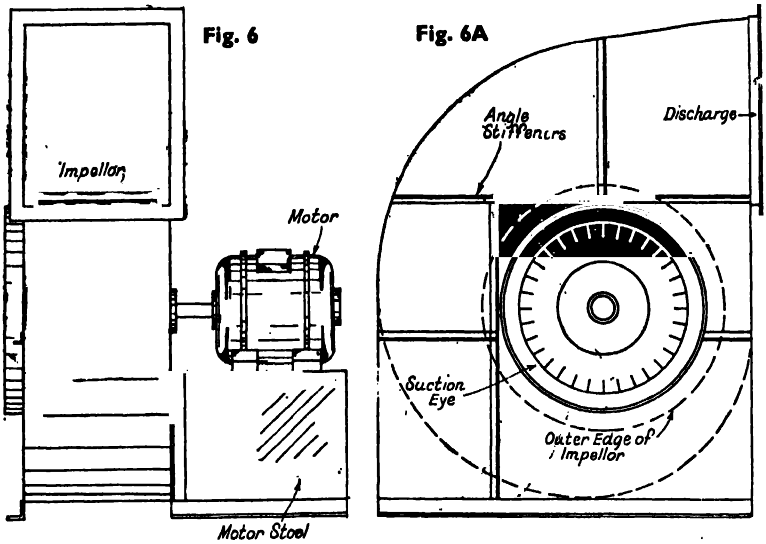
Fig. 5. Propellor fan used for ventilating small hall by extracting air from roof space; air rises through ceiling gratings and is sucked out as shown by arrows.

CENTRIFUGAL FAN

A centrifugal fan is shown in Figs. 6 and 6a, in p. 396. It has a runner similar to an old-fashioned mill wheel. It usually consists of a circular steel backplate to which blades are riveted, the blades lying approximately along radial lines. The number of blades varies from 6 to 64. The greater their number the shorter are the blades. A small fan of the 64-blade type will have blades less than 1 in. long. Fans with 4 to 10 long blades are called paddle-blade fans, while those with a number of short blades are known as multi-blade fans. The blades are curved to enable the air to flow through the fan without shock and to control its velocity as it leaves the wheel.

The runner is enclosed by a steel housing of spiral shape. It carries the suction and delivery connexions and often the bearing for the fan shaft. As the impellor revolves, air is thrown off from its circumference by centrifugal force. Other air flows in at the centre of the impellor to take its place. The air thrown off is collected by the casing and flows out through the fan discharge. Owing to the centrifugal force of the revolving impellor these fans can exert a definite pressure. Centrifugal or cased fans are consequently chosen when there is resistance to the air flow. This is the case with most ventilation installations, since the air must be forced through lengths of ductwork. The friction (*which see*) set up requires a definite pressure to overcome it. This

may be calculated as explained in the article Duct System. To the resistance of the ducts must be added that of the heater



FANS. Figs. 6 and 6A. Centrifugal fan coupled to electric motor : (left), side view showing motor, and impellor in steel housing ; (right), vertical section through fan and housing, indicating suction and discharge openings.

battery, washer, filter or any other obstruction to the air flow.

Choosing the Size. Having found the total pressure a suitable fan is chosen, bearing in mind that this is the sum of the resistance (static) and velocity heads. Makers' lists give columns headed with various pressures, from about $\frac{1}{4}$ in. up to about 2 in. At the left-hand side of the list will be the various sizes of fan. Under each pressure heading will be listed the output of each size and the speed at which it must run. Read down the column headed with the desired pressure, till the requisite output is reached, and read off the size of the fan.

If quiet running is desired, check tip speed of the impellor as described under propellor fans, p. 394.

Some makers list their fans for total pressures instead of static. In this case the velocity pressure must be added to the static pressure. Calculate the velocity of the air leaving the fan by dividing the volume in c.f.m. by the area of the fan discharge in sq. ft. Refer to Table 2, Ventilating Chart pp. 1,104, for the equivalent velocity pressure. The sum of this and the static pressure gives the total pressure. In some cases the term " head " may be used instead of pressure, since the units are inches of water gauge.

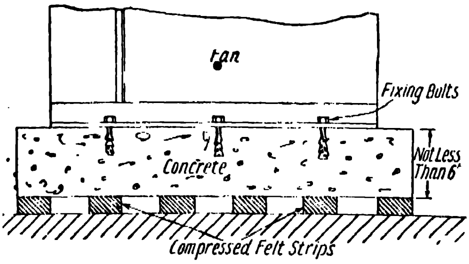
Most makers list three types of multi-blade fans : forward curve, radial blade and backward curve, according to the type of blades on the impellor. The first is most often used, since it is cheapest and smallest for a given duty. The backward curve is usually more efficient and quieter running. The radial blade fan occupies an intermediate position between backward and forward curve.

For the extraction of dust, sawdust, shavings, etc., and the conveying of similar materials, paddle blade fans with a few strong blades are used. The small spaces between the blades of multi-blade fans would quickly become choked if used for extraction.

Fan Drive. It is common practice to use vee rope drive for centrifugal fans. This makes for a quiet installation, since the motor is not in metallic contact with the fan, and electrical noises such as magnetic hum will not be transmitted to the fan and so to the air. Also a cheaper motor may be used, as it may run at a higher speed than the fan, the reduction in speed being effected by different-size pulleys. Vee ropes are vee shape, made of rubber and canvas, and are endless. They have the advantage of being practically noiseless, highly efficient and non-slip ; and enable pulleys of widely different diameters to be used. The pulleys are grooved to take the ropes.

If belt or vee rope is used, the fan motor may be bolted to a wood frame, using timbers not less than 4 in. square. A preferable method is that of Fig. 7, where a pre-cast concrete block not less than 6 in. thick is used. Where quietness is desired the foundation bolts, which are grouted into holes left in the concrete, should be isolated as shown in Fig. 4, p. 395. In addition the block should rest on strips of compressed felt such as mascolite. The connexions between fans and ducts should

be broken by the introduction of canvas sleeves, to prevent the transmission of vibration. Finally, for very quiet running,



FANS. Fig. 7. Firm mounting for centrifugal fan pre-cast concrete block, into which rag bolts are grouted, resting on insulating strips of compressed felt

the air velocity through the fan discharge should not exceed 2,000 f.p.m. For moderately quiet running a velocity of 2,500 f.p.m. may be used.

For the application of fans other articles in this work should be consulted, such as Air Conditioning; Plenum Heating; Ventilation, etc.

Fan Laws. For any fan connected to any installation

1. Delivery of a fan in c.f.m. varies directly as the speed.
2. Pressure given by a fan varies directly as the square of the speed.
3. Power consumption of a fan varies directly as the cube of the speed.

—*L. C. C. Rayner, A.I.E.C.*

FAULT. An electrical defect in a piece of apparatus or wiring installation. Faults are of three kinds: a break in the circuit or *open circuit*; an accidental contact between two parts of a circuit at a different voltage, termed a *short*; and contact between a live conductor and the casing of a piece of apparatus or between a conductor and conduit, termed an *earth*. The last two faults are usually accompanied by an excessive flow of current, which, if not interrupted quickly, will char the neighbouring insulation, possibly melt the conductors, and may even set fire to the surroundings.

Faults may be due to bad workmanship, mechanical damage, the penetration of moisture, or the corrosion of the protective sheath and insulation by chemicals in the plaster, or to similar causes.

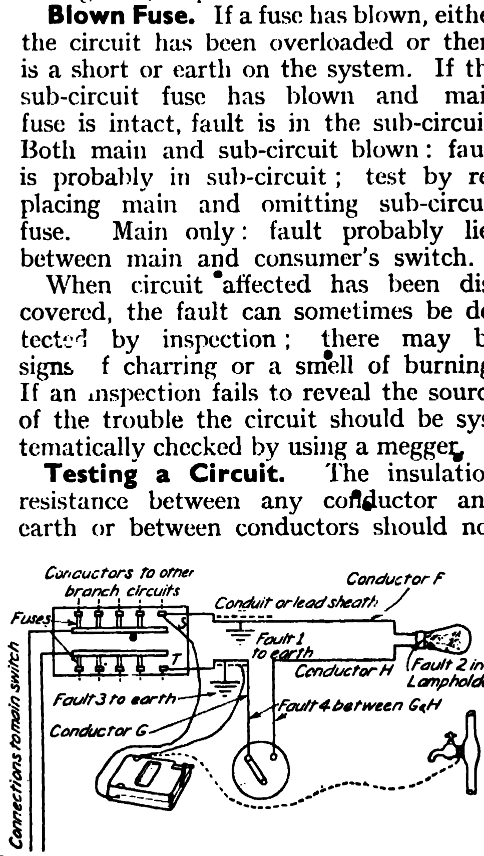
Tracing a Fault. In tracing a fault it is essential to work systematically and to use common sense; it often helps to sketch the circuit and note possible positions of faults; and megger readings, if taken, should be noted. A megger is an instrument used by electricians for testing insulation resistance to earth and between conductors, and to a limited extent it can be used for testing continuity.

The first thing to do when a fault is suspected is to examine the sub-circuit and main fuses. If these are intact, and the supply has not failed, there is probably an open circuit in the system. If the whole circuit is affected the trouble will be at the main switch, or between it and the consumer's fuse-box. If the whole of one circuit only is affected the open circuit will be in the connexions to the fuses concerned, or in the leads between these and the first point. If only one point is affected, find out if the point is alive by connecting a sound lamp across it. If it lights, the fault is in the apparatus or lead between it and the point, including any plugs or adaptors. If it fails to light, the fault may be in the switch (the blades should be examined for contact) or in the conduit; or in the case of a pendant lamp, it may also be in the lamp socket, ceiling rose, or pendant flex.

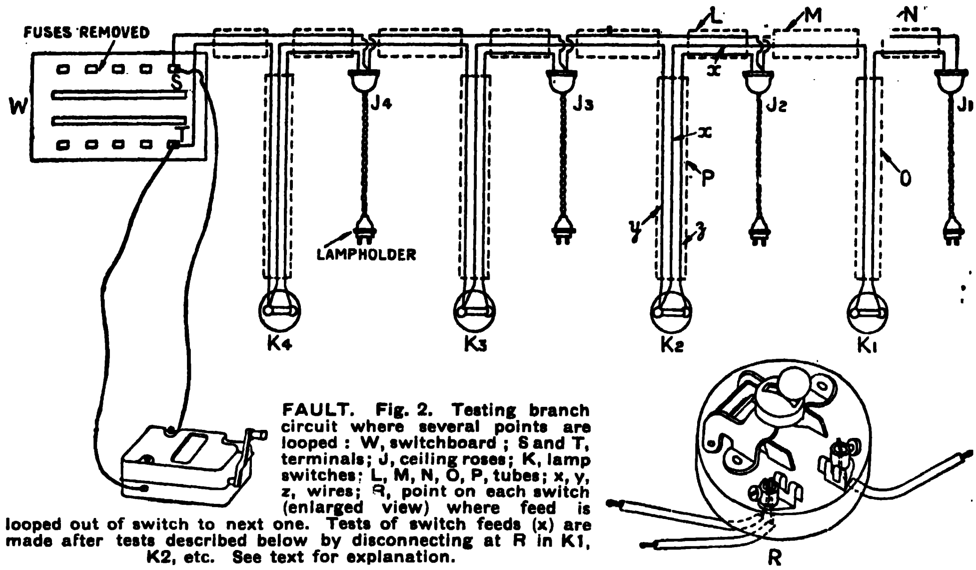
Blown Fuse. If a fuse has blown, either the circuit has been overloaded or there is a short or earth on the system. If the sub-circuit fuse has blown and main fuse is intact, fault is in the sub-circuit. Both main and sub-circuit blown: fault is probably in sub-circuit; test by replacing main and omitting sub-circuit fuse. Main only: fault probably lies between main and consumer's switch.

When circuit affected has been discovered, the fault can sometimes be detected by inspection; there may be signs of charring or a smell of burning. If an inspection fails to reveal the source of the trouble the circuit should be systematically checked by using a megger.

Testing a Circuit. The insulation resistance between any conductor and earth or between conductors should not



FAULT. Fig. 1. Testing faulty sub-circuit with megger connected to sub-circuit switch and to conductors F, G, H in turn: insulation resistance between each conductor and earth, and between conductors, is measured (see p. 398); megger is earthed to tap.



FAULT. Fig. 2. Testing branch circuit where several points are looped : W, switchboard ; S and T, terminals; J, ceiling roses; K, lamp switches; L, M, N, O, P, tubes; x, y, z, wires; R, point on each switch (enlarged view) where feed is looped out of switch to next one. Tests of switch feeds (x) are made after tests described below by disconnecting at R in K1, K2, etc. See text for explanation.

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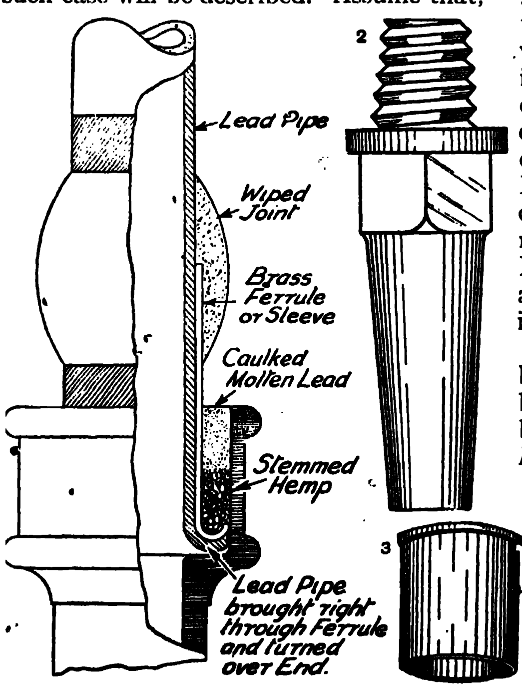
be less than 1 megohm. Before making any test with megger, *open the main switch and remove the main fuses.* To test a faulty sub-circuit, remove the fuses of the circuit concerned from the consumer's fuse-box and proceed as indicated by Fig. 1.

In general, several points are looped into one circuit, as shown in Fig. 2. One such case will be described. Assume that,



FERRULE. Figs. 1-3. (Left) elevation and section showing brass ferrule wiped on lead to make 2-in. lead-to-iron joint. (Top right) screwed water main ferrule to connect lead to hard metal water pipe. (Lower right) spun brass soil pipe ferrule.

with all the lamps removed and the switches "on" the test shows a fault (*i.e.* a short-circuit between conductors), open the switch farthest from the supply, K1, and test again. If the fault clears, the trouble lies in that section. The flex can then be removed from the ceiling rose, the switch closed and the test repeated. This will show if the trouble is in the portion removed or in the switch and conduit, which can be examined accordingly. If the fault does not clear on opening K1, the neighbouring switch, K2, should be opened, and so on until the faulty section is isolated.

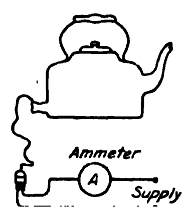
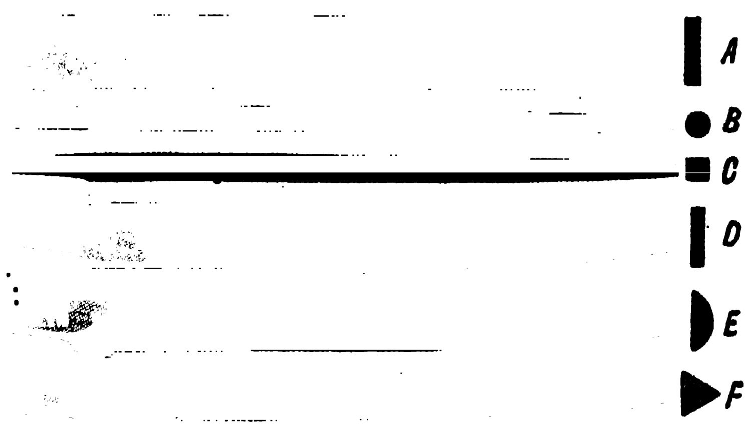


Fig. 3. Testing of electrical appliance for circuit continuity by connecting it to ammeter and supply.

Apparatus such as kettles, irons, etc., can be tested to earth in a similar way; and, by connecting up as shown in Fig. 3, may be tested for continuity of circuit.—*R. A. Baynton, B.Sc., A.M.I.E.E.*

FERRULE (or SLEEVE). Fixed on the end of a lead soil or waste pipe wherever it is connected to a metal or earthenware pipe. It is made of either cast or solid drawn brass and is wiped on to the outside of the lead pipe, as Fig. 1. Being more rigid than the lead, it enables a joint of hemp and molten lead to be made and caulked without the lead collapsing, as would occur if the lead were not protected. Fig. 1



FILES AND RASPS. Fig. 1. A, hand file ; B, round ; C, square ; D, flat E, half-round ; F, three square. (*Thos. Firth & John Brown, Ltd.*)

shows half elevation and half-section of complete joint of lead to metal.

Screwed Ferrule. This (Fig. 2) is used to connect lead water pipe to metal water main or iron pipe. It is made of either cast or hot-pressed brass, and the thread is cut with taper to facilitate fixing and ensure a tight joint.

Wall sleeves, as used in good class hot water and heating work, are dealt with under the heading Sleeve.

FILES AND RASPS. The older method of making files is by cutting the teeth by hand with a chisel, and a mechanical process is also employed with the same object. In the single-cut file there is one row of teeth, lying at an angle across the file. In the double-cut, another row of teeth crosses the first, leaving a row of points standing up.

Obviously the single-cut will give a smoother action and leave a smoother surface on metal filed ; but the double-cut file is usable for softer metals and for materials like wood, bone, ivory, etc. Apart from the two cuts, there are grades of coarseness or fineness. In the single-cut these are smooth, second-cut, middle-bastard, between-bastard, middle and rough. In the double-cut the grades are dead-smooth, smooth, second-cut, bastard, middle and rough. The shapes most used by the plumber are the half-round, square, triangular and the round or rat-tail file.

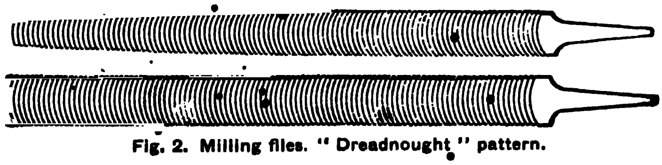


Fig. 2. Milling files. " Dreadnought " pattern.

Various shapes of file are illustrated in Fig. 1, and milling files are shown in Fig. 2. Fig. 3 shows an enlarged view of file teeth cut by a hobbing process. The teeth are under-cut to a certain extent and do not clog so readily as those of the chisel-cut file.

Using the File. Though in the trades covered by this encyclopedia the file is seldom used for close or accurate fitting, and is employed rather for cleaning up, removing burrs, etc., it is as well to understand the proper method of use.

Fine sense of touch and an ability to move a file in a true straight line are not easily acquired. There is an inevitable tendency of the hands to move in arcs from the shoulder joints. The aim should be

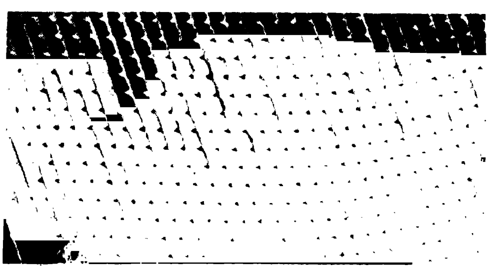
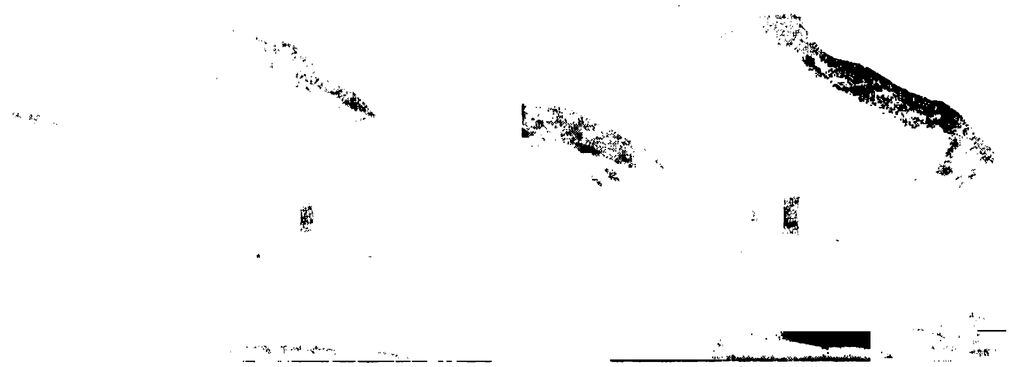


Fig. 3. Enlarged view of " Millenicut " milling file teeth are hobbed out in milling machine. *Thos. Firth & John Brown, Ltd.*

to try to pick out the central area of the surface being filed, and to avoid the metal near the edges. In doing this the worker will almost unconsciously fall into the proper action.

Files are not straight, but are slightly bellied in their length, so that it is possible to pick out any particular portion of a surface and remove metal from that alone.

The conditions of heavy and light filing (Figs. 4 and 5) are very different in regard to the proper attitude. In the first it is essential to throw much of the weight of the body on the file, to produce a good bite and reduce fatigue of



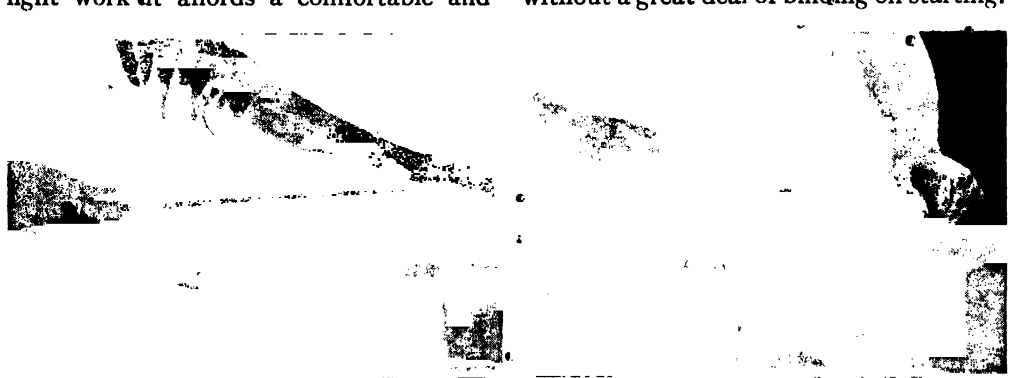
FILES AND RASPS. Figs. 4 and 5. Using the file : (left) heavy filing, grasp of hands on handle and point to give greatest pressure with least fatigue ; (right) light filing, gentle but firm hold for delicate touch.

the arms ; but in the second there is no such necessity. For heavy filing, the worker should stand well away from the vice, with the feet spread apart and the left one forward of the right (for a right-handed worker). When the file is thrust forward, the front foot should be relaxed so as to throw as much as possible of the weight of the body on the file, and the rear foot should be used to push forward and relieve the arms.

On the backward stroke the front foot again takes the weight of the body as it resumes an upright or nearly upright position. In ordinary and light filing the upright attitude is assumed all the time, and the arms impart all pressure.

In Fig. 4 the grasp of the hands on the handle and the point of the file is such that the greatest pressure can be given with the least amount of fatigue. The thumb of the right hand should always be on the *top* of the handle. There is no need to grip tightly, because this does no good and tires the muscles rapidly. But the manner of grasping seen in Fig. 5 will not enable heavy filing to be performed, while for light work it affords a comfortable and delicate touch, with good control of tool. Methods of facilitating removal of metal with coarse files are illustrated by Figs. 6 and 7, showing respectively the device of sweeping the file to the left as it is pushed forwards, and the alternative of disposing the file at an angle, and crossing the direction after every few strokes, so that the ridges are easily topped off. These methods are especially suitable for the heaviest slogging, because the weight of the body can be thrown from right to left simultaneously with the forward movement, and this is much less fatiguing than the forward movement by itself.

Rasps. The cutting surface in the rasp is much coarser than in the file, and the teeth are formed in a different manner, standing up as though a sharp point had been driven into the surface at an angle of about 45 degs. The outer edge is serrated and may be used for cutting soft metals. The tool is made in various grades of tooth, and the most convenient for the plumber is a medium smooth cabinet rasp, half-round in section. This type will be found to work easily on lead, without a great deal of binding on starting.



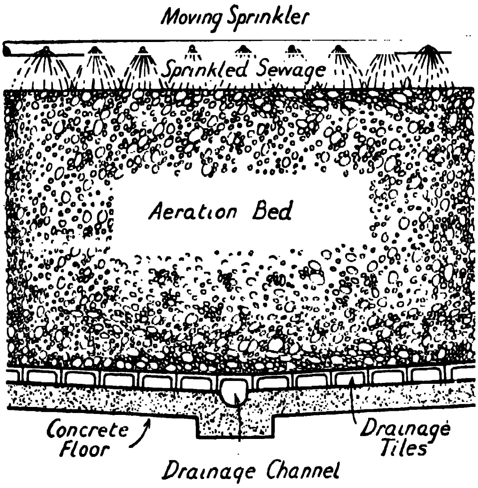
Figs. 6 and 7. Coarse filing : (left) first stroke—sweeping file forwards and to left, weight of body on file, rear foot used to push forward ; (right) second stroke—body more upright, weight shifted, change in grasp.

FILTERS AND FILTRATION : (1) SEWAGE TREATMENT

By H. C. H. Shenton, Hon. F.I.S.E., F.R.San.I.

Describing the different types of filter bed and outlining methods of treating domestic sewage in these. Further information is given under Activated Sludge ; Bacterial Treatment. See *also* Sewage Treatment ; Sprinkler.

The earliest form of sewage filter was porous land into which sewage was allowed to percolate. Later, land was specially prepared in order to facilitate the process ; and later still, areas of made ground carefully drained were used for the purification of sewage. Filter beds of sand and gravel were also employed for the treatment of liquid sewage, and in many



FILTERS AND FILTRATION : SEWAGE. Fig. 1. Percolating or sprinkler filter (see text) : sewage is sprinkled over surface, air circulates freely upward and downward through bed, and drainage is free.

cases proprietary materials were used in the filters in order to increase their efficiency.

Contact Bed. About the end of the nineteenth century filters made of much coarser material, working on a different principle, came into use. These were filled with coke, generally of about 1 in. gauge or smaller, and were called "contact beds." Other filling material of various sizes such as clinker was also used. In working the contact bed the outlet valve is closed and the bed is allowed to fill with sewage, which is held in contact with the filling material for a period of one or two hours ; after this the liquid is drained off by opening the outlet valve. The bed is then allowed to stand empty for ...or aeration, the air being ...body of the filter as the ...iid falls.

Continuously Aerating Filter. This, a later development, was designed to give a higher degree of aeration to the sewage. It is generally called a " percolating or sprinkler filter." Sewage is sprinkled over the surface of a bed of material which is generally of a gauge ranging from 3 in. to ¾ in. in size. The sewage is highly aerated in the process of sprinkling, and also in the bed itself, because there is free ventilation through the mass of material. This is the type in general use at the present time (Fig. 1).

There are, however, many other types, each of which has its special applications. There is the upward filter, which is actually a submerged screen of material supported on a grating through which the sewage rises. Its main object is the interception of solid matters. Fine-grained sand filters are sometimes used for the final purification of filter effluent ; these work at a relatively slow rate and must be of correspondingly large area.

Recently in America filters of small size have been used, through which sewage effluent is passed at a rapid rate. This causes clogging, which is removed by back washing effected by a reversal of flow through the filter. The magnetite filter, consisting of a shallow layer of crushed magnetic iron ore, resting on a bronze screen, has been installed on a large scale in America. The sewage

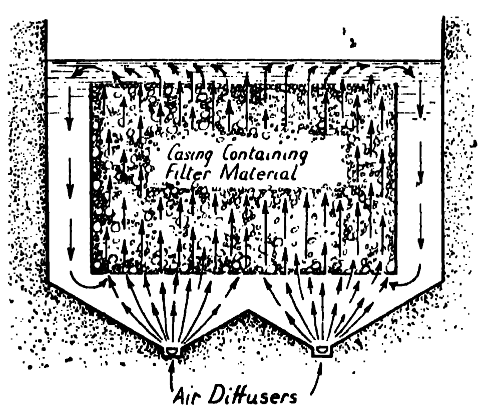


Fig. 2. Type of aeration bed : submerged filter bed through which compressed air is blown from below.

passes through this layer, and upward washing away of the intercepted solid material left on the filter surface is facilitated by constantly moving solenoids, which cause temporary disturbance of the material as they pass.

Yet another form of filter (used in Germany and America) consists of material submerged in liquid sewage in a tank through which diffused air is blown. These filters work in series, and the sludge which collects is drawn off at the bottom.

Covered percolating filters with forced aeration are also in use, and it is claimed that their efficiency is three times that of the ordinary percolating filter.

In certain other cases sewage is discharged continuously at a rapid rate on to percolating filters working in series, with recirculation of the effluent.

Filter beds are also used for the dewatering of sewage sludge. These are generally of simple construction, consisting of a layer of material from 1 ft. to 1 ft. 6 in. deep, with under-drains.

FILTRATION TREATMENT OF SEWAGE

The ordinary sewage filter consists of a mass of material arranged in suitable form and depth over which sewage is sprinkled and through which it percolates in contact with the air. The filter may be enclosed by a surrounding wall or may be open at the sides. The drainage is very important, and for this reason the arrangement of the material and its gauge, together with the under-drainage, are essential features. The practice of providing a false bottom of perforated tiles with an air space below is to be commended, although it is not universal, and in many cases reliance is placed upon a bottom layer of coarse material, with open jointed drain pipes. A concrete floor is provided, so arranged that the effluent runs into a suitable channel.

The proper distribution of the sewage over the surface of the filter is all-important. It is effected in different ways in accordance with the dimensions and area of the filter. In Britain the most common method of application is that produced by rotary distributors on circular filters, the distributor being made to revolve slowly by the force of the liquid discharged through small jets in the arms of the distributors. In the case of large filters of rectangular form power driven distributors are used; but there are also various forms of distributor worked by the action of the sewage flow. In other cases distribution is effected by means of fixed spray jets, but these are more common in America than in Britain.

Treatment by Aerobic Bacteria. The main object of the filter is to bring the sewage into contact with purifying bacteria. The bacteria exist in the sewage itself, but the filter provides an environment for their increased development. These purifying organisms are active only in the presence of air, and their action is promoted by the absorption of oxygen in the liquid sewage. It is therefore necessary that the sewage should be delivered over the surface of the bed by sprinkling in the air, and for this reason sewage distributors are arranged to produce the sprinkling action of rain. The filter itself is arranged as an aeration bed for the same reason, the straining action being of secondary importance.

Settling Tanks. Before sewage is sprinkled over the filter the solid matters are intercepted from the crude sewage. This is generally effected by passage through settling tanks and the delivery of the tank effluent before septic conditions (due to the decomposition of the sewage) have been produced. If a septic sewage is sprinkled over a filter, aerial nuisance will arise.

Action of the Filter. Liquid sewage sprinkled over the surface of the filter passes down through the body, the object being that it shall form a thin film over each particle and that there shall be no direct stream through any part of the filter. The passage through the filter must be slow enough to allow time for the liquid and material brought into contact with the purifying organisms to undergo the necessary changes. The organisms adhere to the surfaces of the filter material.

When sewage is first applied the degree of purification effected is relatively small, but it increases as the bacteria develop and form colonies on the filling material. A filter, therefore, generally takes some months to reach its highest stage of efficiency, and the rate at which the bed matures is largely dependent upon atmospheric temperature, the organisms being more active at a high temperature than during the low temperatures of the winter months.

In order that the bacterial action may be perfect the filter material must be of such grade and quality that the air may have access to all parts. Thus, filters are formed of hard, broken stone, well-burned clinker, or other material which will not disintegrate and which is free from dust.

The grade of material forming the filter bed varies in accordance with the nature of the sewage and with the degree of purification required. Speaking generally, for an ordinary domestic sewage a layer of material 6 in. thick, varying between 2 in. and 3 in. in diameter, is laid at the bottom on the floor tiles; and above this, up to the surface, the filter is formed of material of an average diameter of 1½ in., being not less than 1 in. and not more than 2 in. in gauge.

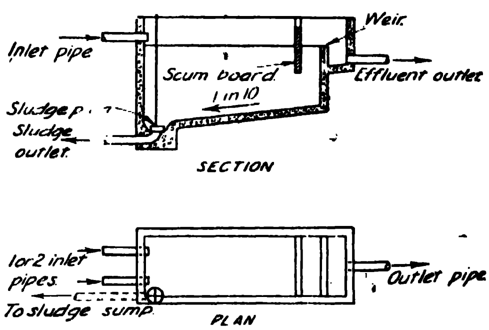
The depth of the filter material is generally about 6 ft., but filters of a depth of 4 ft. 6 in. or of depths exceeding 6 ft. are often used with satisfactory results. Sometimes it is expedient to provide a finer top layer of material (say, of ¾ in. gauge, with a depth of 12 in.), but there can be no fixed rule in this matter, and each case must be treated on its own merits, in accordance with conditions and experience.

CAPACITY OF FILTERS

The quantity of sewage purified by a filter of a given size is entirely dependent upon its quality and upon the preliminary treatment it receives before it reaches the filter. In the recommendations of the Royal Commission on Sewage Disposal contained in their fifth report, certain important figures were given. The Commission considered the treatment necessary for sewages of different strengths in order to produce an effluent of a standard quality suitable for discharge into ordinary rivers and streams. They also considered the gauge of the filtering material to which their figures referred. "Coarse" material was defined as that which will not pass through a 1 in. sieve; "medium" as that which will pass through a 1 in. but not through a ½ in. sieve; and fine material as that which will pass through a ½ in. sieve, the gauge of the material being dependent upon the quantity of suspended matter present in the sewage.

For sewage which has passed through a small grit interceptor only, the Commission advised that 1 cu. yd. of filter of coarse or medium material should be provided for every 15 gallons of strong sewage treated per day; this quantity was increased to 25 gallons for sewage of average strength, and to 40 gallons for weak sewage. If the sewage had passed through a septic tank as a preliminary, these figures were respectively 45, 70 and 100 gallons per cu. yd. per day, according to the strength of the sewage; and the same allowance was advised in the case of sewage which had passed through settling tanks. Where the sewage had received elaborate treatment, aided by chemicals, for the removal of solids in suspension, the allowances were much higher, and very fine grade filters were suggested for treatment. In general practice at the present time it is found that for an average sewage of a domestic character, an allowance of from 50 to 70 gallons per cu. yd. per day is sufficient, but the presence of trade wastes and the dilution of the sewage may make a very great difference in these figures. The quality of the effluent required is also a very important factor.

Humus Tank. The effluent from a filter is generally passed through a tank in which any solid matters washed through filter are intercepted; this is called a humus tank, humus being any light organic matter. This is suspended in the



FILTERS AND FILTRATION: SEWAGE. Fig. 3. Humus or settling tank, used to retain light solid matter remaining in effluent from filter.

liquid and must be allowed to settle before the effluent is discharged. Fig. 3 shows the tank, with scum board: the outlet is from a channel into which the liquid flows over a weir, solid matter being held back by the scum board. Humus tanks are generally provided in duplicate to facilitate cleaning, each holding about one-twelfth of the day's flow. The provision of larger humus tanks may be desirable under certain conditions.

FILTERS AND FILTRATION: (2) WATER PURIFICATION

By E. H. Vick, A.M.Inst.C.E.

A description of the chief types of filter and an explanation of filtration methods. The general question of water purification is treated under the heading Water and Water Supply : (3). See *also* Chlorination.

Filtration is one of the most important processes in the purification of water, most of the other processes such as aeration or chlorination being supplementary ones designed to effect further purification with which the filter will not adequately deal. The object of filtration is the removal of suspended matter, particularly the very finely divided suspended solids, and also the removal of harmful bacteria. The heavy and coarse particles of solids are best removed by previous storage or by sedimentation.

The chief classes of filters are :

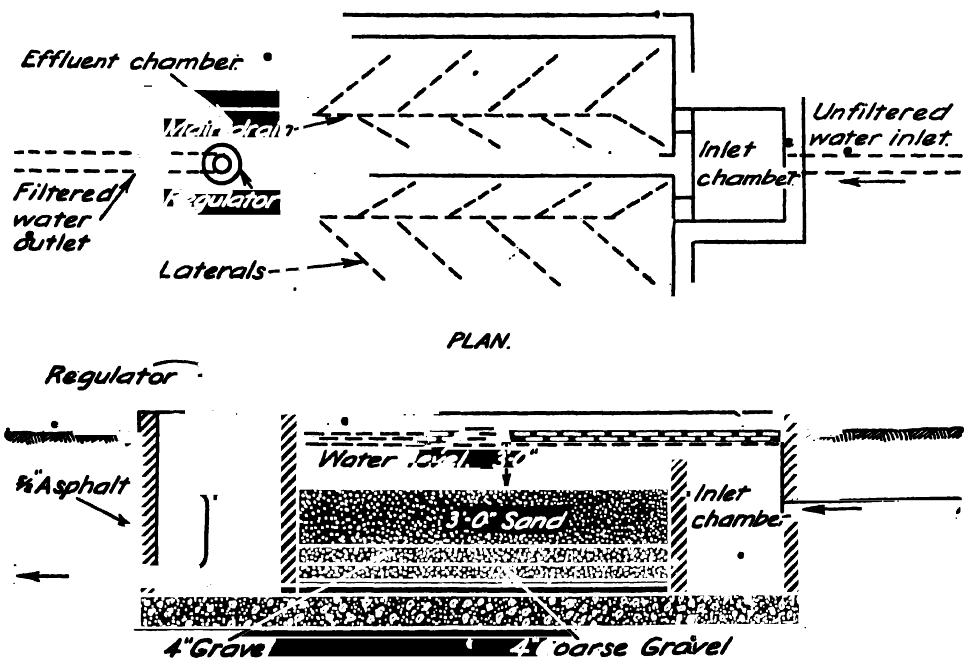
(*a*) Sand filters, trickling type ;
(*b*) Mechanical filters ;
(*c*) Small domestic filters.

A. SAND FILTERS

A sand filter consists of a shallow concrete or brick tank, having a floor composed of brick drains, or of drainage tiles, and containing a bed of fine sand. The unfiltered water is discharged on to the top of the sand, runs slowly through the sand and is collected by means of the drains in the floor and led away to the service reservoir.

Action of the Filter. The first action which occurs in a sand filter is that when water containing suspended matter is run through the clean sand, all the particles of suspended matter that cannot get through the interstices between the sand are retained. The top layer of sand soon gets comparatively choked with suspended matter, and most of the mechanical straining action is carried out by the top layer, usually the first inch or so of the sand. Thus a dirty filter is more efficient than one that has just been cleaned. It is found that this very thin screen of mud is able to make a turbid water quite clear.

In cases where the water contains particles so finely divided that they are not caught by the clean sand, coagulation has to be resorted to. This consists in



FILTERS AND FILTRATION (Water). Fig. 1. Sand filter to remove suspended matter in water : shallow tank with main and lateral drains, and containing graded filtration material.

mixing with the incoming water a solution of sulphate of alumina, thus causing a film of alumina to be deposited over the sand bed within an hour or so. This artificial film is as effective in its straining as the natural film mentioned earlier.

Soon after putting a sand filter into operation a film consisting of vegetable species commences to grow upon it. This film grows more quickly in the case of water from rivers and streams ; while with water from springs or similar sources it may not develop at all. The film of gelatinous matter improves the efficiency of the filter, the various forms of low vegetable growth being destructive to bacteria. The film, of course, grows more rapidly in spring and summer and in warmer climates. It is efficient only as long as its surface is continuous and unbroken. When it gets too thick, parts of the film may detach themselves from the surface of the sand and rise to the top of the water. The water will then find its way through the exposed surface of the sand and escape the filtering benefits of the surface film. A break in the film is sometimes caused by insect larvae, particularly a reddish worm which burrows in the sand and later emerges as a winged insect. It leaves numerous holes in the sand and surface film, through which the water escapes without purification.

Further purification is effected by the body of the filter, principally the reduction of dissolved organic matter. The sand in the body of the filter gradually gets covered with a coating of slime, getting thicker and more complex in its structure as it grows. This slimy coating acts in a similar manner to that in a sewage percolating filter (*see* Filter : 1), and has the power of absorbing gases and dissolved organic matter from solution. This slime is full of bacteria which live on the organic matter absorbed and destroy it. The bacteria also act upon the albuminoid ammonia in the unfiltered water, and by a complex system of decomposition the albuminoids are split up into water, nitrates and ammonia.

Design and Construction of Sand Filters. Sand filters are suitable for any size of works, and can be made of any shape to suit the natural layout of the ground available.

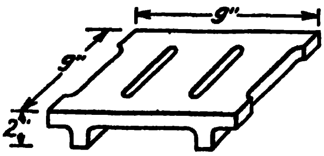
The flow allowed through a sand filter is usually taken as about 2½ million gallons per acre per day. For a small installation, say for a country house or estate, having a maximum demand of 1,500 gallons per day, this would give an area required of about 26¼ sq. ft. ; or, say, 8 ft. by 4 ft., to allow for a reserve of area when the filter gets clogged. Two filters are essential so that one can be in use while the other is being cleaned.

The thickness of the sand is the next consideration. This will depend partly on the head of water available, and partly on the degree of impurity of the water. A turbid water with a small bacteria content will require a smaller thickness of sand than a clear water with a large bacteria content. This is because bacteria are mostly removed by the film of slime in the body of the filter, whilst suspended matter is removed by the vegetable film and the straining action of the sand. A common depth of sand for small filters is about 3 ft., and this will probably be reduced to 2 ft. by successive scrapings of the top film. The depth of water over the sand is usually 3 ft. to 3 ft. 6 in. ; a smaller depth causes the water to become unpleasantly warm in summertime, and a greater depth is liable to rupture the surface film.

Filters may be constructed of brickwork, mass concrete, or reinforced concrete, depending upon the cost of the materials available locally. However constructed they must be watertight, or unfiltered water containing bacteria may find its way from the inlet chamber, via the subsoil and back into the outlet chamber containing the filtered water. Subsoil water might also leak in. There are several methods of obtaining watertightness—by means of clay puddle, about 18 in. thick against the outer wall, or by means of a layer of asphalt or bitumen. The floor of the filter should be of concrete, about 4 : 2 : 1 mix, and brought to a very smooth face by rendering on the top surface so that no growth occurs on the filter floor.

If the walls are in brickwork they should be built of good hard engineering bricks jointed in 3 to 1 cement mortar, and of ample thickness to withstand the water pressure. A layer of ⅝ in. asphalt or 18 in. of good clay puddle should be placed against the outside of the walls. A main drain and laterals should be formed in the floor ; they may be half-round

recesses formed in the concrete, or be composed of half-round glazed stoneware channels. Over the floor is laid a false floor of bricks on edge or of special filter tiles (Fig. 2). A layer of 4 in. of $\frac{3}{8}$ in. gravel is laid over the tiles, and a layer of 4 in. of $\frac{1}{8}$ in. gravel over this. The sand is then placed in the filter to a depth of about three feet.



FILTERS AND FILTRATION (Water). Fig. 2. Special filter tile for false floor of sand filter.

Sand. The sand used should be fine quartz, washed free from clay and carbonates of lime. It is important that the sand shall be of as uniform a grade as possible, so that the resistance to the water is even over the whole filter. Sand from sand dunes is usually uniform in grade, while river and pit sands may vary considerably. The best size of grains is probably 1/100 in. to 1/50 in. diameter.

Management of Sand Filters. Sand filters of small size may be managed by comparatively unskilled labour. It is necessary to control the amount of water passing through the filter, since as the filter gets clogged so the rate of filtration will decrease unless the difference of head is increased to maintain uniformity of filtration. One method is to increase the depth of unfiltered water over the sand bed; the other is to keep the level over the sand the same and lower the water level in the effluent chamber. There are several automatic devices manufactured to do this under either method.

Cleaning. The filter is cleaned by removing the top layer of vegetable growth and about $\frac{3}{8}$ in. of sand. The water should not be completely drained from the filter, or the slimy coating in the body of the sand, (together with the micro-organisms) will be detached, and until this film is built up again the filter will lose its property of detaining bacteria. The water should only be drawn off so that its level is about 4 in. underneath the top of the sand layer. After cleaning, the first flow of water should go to waste, but it is not necessary to wait for the top film of vegetable growth to form, as filtering action takes place by means of the slime coating in the body of the filter.

The frequency of cleaning the filter will depend upon the degree of pollution of the unfiltered water and the time of the year. The filter will require more frequent cleaning in summer than in winter; in a severe winter the vegetable film will probably not grow at all.

Washing the Sand. If the filter is very small and a suitable sand can be obtained locally, the sand scraped off is normally thrown away. This process goes on until the sand bed is reduced to a thickness of 2 ft., when new sand must be obtained. If it is necessary to wash the sand in a small installation, this may be done by hosing it while it lies on a concrete platform well away from the filter bed. Machines for washing sand are made by specialist firms and are usually installed only at fairly large plants.

If in a very exposed position a small sand filter may need covering in very frosty weather, to avoid ice forming on the top of the water.

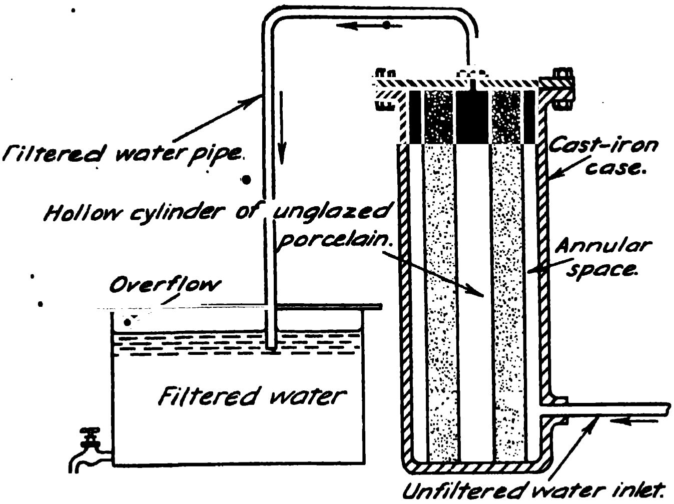
The loss of hydraulic head through the filter will usually be of the order of 3 ft.

B. MECHANICAL FILTERS

Mechanical filters are those in which the process of filtration is speeded up many times as compared with the ordinary trickling sand filter. They are usually of cylindrical form, built up of wrought iron or steel plates, and contain a bed of sand or crushed quartz. One filter of this type (Candy Filter Co.) employs a substance known as polarite in addition to the sand. Polarite has great purifying properties, and is particularly adapted to remove iron from the water supply.

Mechanical filters have certain advantages over slow sand filters. Owing to their high rate of filtration they take up less space for a given quantity to be filtered. The filtering media are not likely to be polluted by outside causes, and the cleaning process can be carried out in a few minutes by turning two or three valves. On the other hand, they need frequent cleaning, sometimes twice a day, and to be effective they require handling with more expert knowledge.

As the rate of filtration is so high the natural filtering skin has no time to form, so an artificial film is employed instead. This is formed by means of a coagulant, usually sulphate of alumina (as in the case of the ordinary sand filter referred to in pages 404-405). The coagu-



FILTERS AND FILTRATION (Water). Fig. 3. Domestic filter : small cylindrical vessel fixed to main tap, containing activated charcoal, or preferably unglazed porcelain or kieselguhr.

The washing process takes from three to five minutes.

Candy Pressure Filter. A section of a vertical unit is shown in Fig. 5. The filtering bed has a total depth of 3 ft. 6 in. and is composed of graded pebbles and sand together with an appropriate quantity of polarite. The latter is a black granular insoluble material which enables dissolved iron to combine with oxygen instantaneously, so that the iron in solution in the water is converted to the

lant is mixed with the incoming water, and has the two-fold effect of bringing down some of the very minute particles of suspended solids and of forming (in a very few minutes) the filtering skin.

Bell Pressure Filter. The mechanically agitated standard type is shown in Fig. 4. The filter bed is of fine sand. The agitating gear comprises horizontal arms on a vertical rotating shaft. After being mixed with a suitable amount and kind of chemical, the water is passed into pipe F and through inlet valve H into top block on shell M and into top of filter shell L; then, after passing through filtering material, it is collected by strainers E and passes out through bottom pipe into main filtered water discharge pipe and out through valve K.

In washing, clean water is passed through filter from bottom; at the same time the agitating gear is put in motion. A current of water is passed through top pipes H into hollow shafts D, hollow arms G, and out through back-pressure valves A.

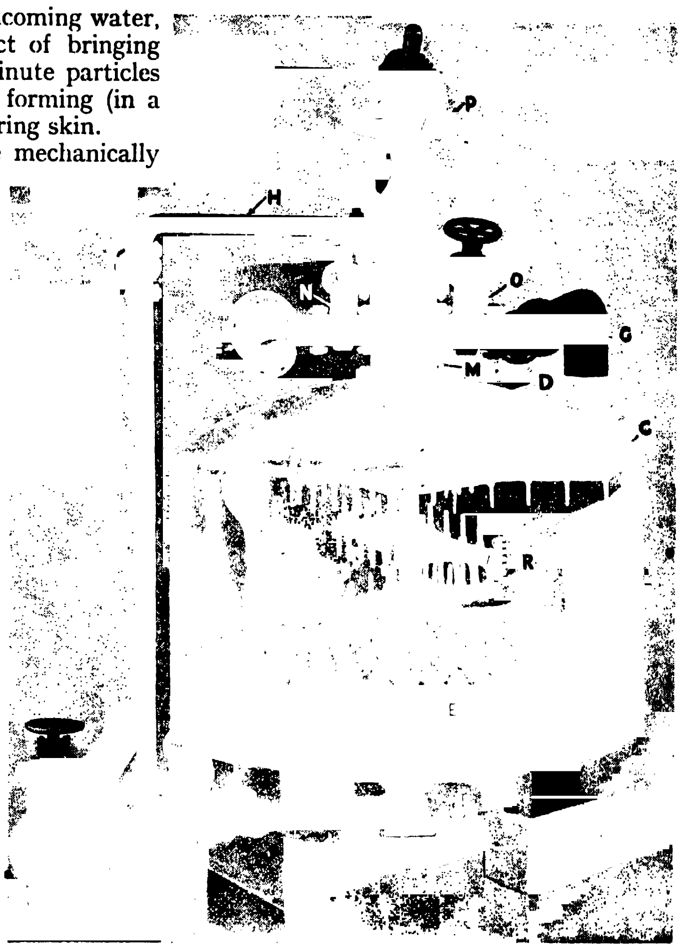


Fig. 4. Pressure filter, mechanically agitated type : B, rakes on hollow wash arms C; I, vertical wash valve; N, inlet valve for dirty water; O, wash out valve; P, bevel wheels; R, end rakes. See also text.
Bell Bros., Ltd.

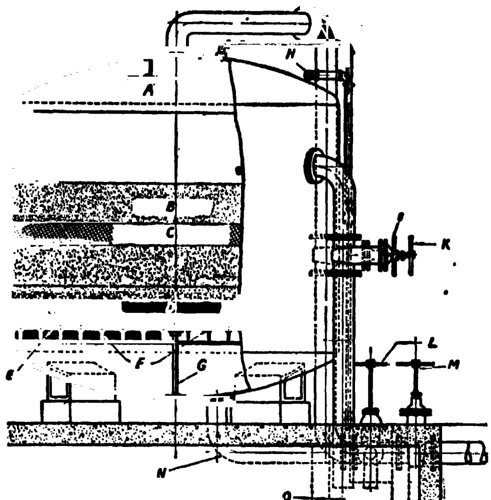
insoluble state in a few seconds. The iron is retained in the filter bed and is removed in the form of a liquid mud when the filter is cleaned. Cleaning becomes necessary after from 24 to 72 hours' normal working. It is accomplished by intense agitation of the sand by compressed air (5 min.), followed by an upward flow of water (4-8 min).

C. DOMESTIC FILTERS

Filters for domestic use (see Fig. 3, in page 407) are usually small cylindrical vessels, suitable for fixing directly to the main tap. They usually contain activated charcoal, unglazed porcelain or kieselguhr.

With all types frequent cleaning is essential. The filtering substance quickly gets coated with slime and bacteria; the rate of filtering is slowed up, and eventually bacteria are washed through with the filtrate.

Charcoal filters get clogged comparatively quickly. Probably the best filtering media are unglazed porcelain or kieselguhr. A good head of water is necessary to obtain even a moderate flow, so that sometimes the main tap is kept turned on, the filtrate dripping into a covered container fitted with an over-flow and a draw-off tap.



FILTERS AND FILTRATION: Water. Fig. 5. Polarite pressure filter; A, spreader plate; B, sand bed; C, layer of polarite; D, graded gravel; E, nozzle plate; F, nozzles; G, stay rod; H, air main; I, unfiltered water inlet valve; K, washwater outlet valve; L, drain valve; M, filtered water outlet valve; N, filtered water outlet pipe; O, washwater drain sump.
Candy Filter Co. Ltd.

FINANCE: FOR PLUMBER & HEATING ENGINEER'S BUSINESS

By Reginald A. Price, A.C.I.S.

General information on business methods, the keeping of accounts and similar matters, have been given in such articles as Accounts, Book-keeping, and Business Methods. Here Mr. Price deals with the financial side of business, having specially in mind the man who has lately started in business for himself. See *also* Shop.

The subjects here discussed are: (1) working capital; (2) opening a banking account; (3) the services rendered by banks, with particular reference to loans and overdrafts; (4) precautions in regard to cheques; (5) debt collection methods; and (6) receipts.

Working Capital. Before embarking upon business, the plumber and sanitary engineer should consider his financial resources, as insufficient capital is a frequent cause of failure. After estimating the amount required to equip the business (premises, machinery, plant, tools, etc.), the balance of cash, or working capital should be sufficient for the following purposes:

(*a*) To purchase and maintain an adequate stock, without which it is difficult to execute prompt work. Customers prefer to choose goods that can be seen rather than be guided by catalogues.

(*b*) To finance a reasonable amount of book debts. Customers on the whole will go where a moderate length of credit is given.

(*c*) To facilitate prompt payment to merchants. Loss of cash discounts is a serious drain on a business.

(*d*) To give a margin for taking advantage of special offers by merchants, or to lay in a stock of goods which are about to increase in price.

A. BANKING FACILITIES

Opening a Bank Account. Before opening a new account it is usual for a bank to ask for an introduction. A form will be provided for this purpose. A specimen signature is required, and when signing cheques the same form of signature (as in the specimen) should always be used. A pass book will be issued, in which the bank records all transactions between the customer and itself. Some banks have

adopted a loose leaf statement form which is posted up day by day. The customer keeps the leaves in a cover provided by the bank. The current statement may be had upon application. An advantage of this method is that there is no need for the book to be left at the bank for writing up. Arrangements may be made for the loose leaves to be sent to the customer at any interval he desires. A weekly interval is suggested, in order that a prompt reconciliation with the Cash Book may be made.

For the purpose of paying cash and cheques into the bank, a paying-in slip book is issued. It is preferable to use a book rather than loose slips. Finally, a cheque book is provided. This should always be kept under lock and key when not in use, as loss may be sustained should the book get into dishonest hands.

Functions of a Bank. The principal services rendered by a bank are :

(*a*) It pays out of its customers' accounts cheques drawn on those accounts. The bank acts as an agent for its customers in this respect, honouring cheques drawn up to the total of each account, or up to an agreed overdraft.

(*b*) It collects cheques for customers. Cheques which have been paid into an account must be sent by the customer's bank to the bank upon which they are drawn, for the purpose of collection.

(*c*) It acts as a referee. Merchants usually ask for a reference before opening new accounts, and a banker's reference is always acceptable. It stands to reason that the customer must keep his account in good order, or the reference will be worth little.

(*d*) It takes custody of customers' securities.

(*e*) It makes loans.

Bank Loans and Overdrafts. Provided security can be offered, a bank will grant a loan or overdraft.

A ***legal mortgage*** is possible where the borrower owns his premises. The property is conveyed to the bank, but remains in the borrower's possession as long as he fulfils the covenants in the deed. These are to pay interest, keep the property insured, pay rates and taxes, and repay the loan when required. The bank agrees to re-convey upon payment of principal and interest. This method is too expensive for a short loan.

An ***equitable mortgage*** is a more usual procedure. The title deeds are merely deposited with the bank, together with an undertaking to execute a legal conveyance should the bank require.

Debentures are another form of security, but these are available only to limited companies. A debenture usually (though not necessarily) gives the lender what is known as a floating charge upon all the assets of the company. The effect of this is to make the bank a fully secured creditor.

Deposit of securities is one more method of inducing a bank to grant a loan. If the customer possesses share certificates, or perhaps a life policy with a good surrender value, these may be lodged as security.

A ***guarantee*** by some approved person may secure an overdraft should the customer be unable to adopt any of the other expedients.

Cheques. The following important points should be noted. Cheques should always be crossed (except those to be used when cash must be obtained, say, for wages). The effect of a crossing is to prevent fraud or loss to the drawer, for a crossed cheque is payable only through a banker. The payee cannot cash the cheque ; he must pay it into his account. Another safeguard is to write the words " not negotiable " upon the cheque. The effect is to prevent a fraudulent negotiation. Normally, a cheque is a negotiable instrument ; that is, it may pass through several successive holders before eventually reaching the bank upon which it is drawn. The words " not negotiable " remove this attribute. Care should be taken when drawing cheques to see that no loopholes are provided for fraudulent alteration. For example, when writing a cheque for £10, do not leave room for the insertion of a " 1 " in the figures and " one hundred and " in the written portion, thus converting the cheque into one for £110. The written figures should commence with a capital letter and immediately after the printed word " Pay." The figures should be indicated thus: £10–0–0.

B. DEBT COLLECTION

Before allowing extensive credit to a new customer who is a stranger it is advisable to obtain a reference. The customer may be asked for a banker's

reference, though discretion should be used when considering this method. An alternative is to make inquiry through one of the trade protection societies.

Promptly rendered Invoices form the basis of successful debt collection. Many customers are found to be more ready to pay when efficient workmanship is still fresh in memory.

A *statement* showing the amount outstanding should be rendered at least once a month. This monthly review of debts should be made critically, noting in each case the date of the debt. Select for special attention all statements which are in respect of debts of, say, 3 months' standing. If the amount of any particular item is considerable, and the customer appears at all doubtful, immediate action should be taken; but the average debt may be dealt with as follows:

Reminder slips for affixing to monthly statements are available, graded from a polite request to a stern demand. These are very effective, but a more personal note is struck by means of letters.

Letters may be graded similarly to the reminder slips. Suitable letters should be composed, and a stock of each prepared by the "super-typing" process (through any good stationer). Much time in typing letters will thus be saved.

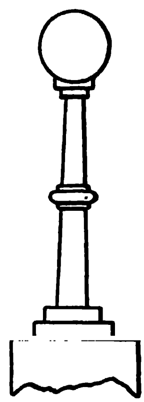
A *record* of collection efforts should be maintained. This may be made in the debtors' ledger, but a better idea is to keep a card index. As soon as it becomes necessary to "follow up" a debtor, make out a card and record what is done from time to time. The cards may be ruled after the manner of the specimen shown in opposite column. When a "card debt" has been paid, the card should be removed and preserved in a separate drawer. A collection of such cards will serve as a "credit index" for the future.

Debt Collection Card

Name....Blank, Robert. Ledger Fo. 101.
Address..4, High Street, Blankton.

Date	Amount	Period	How dealt with
19..	£ s. d.		
Jan. 31	12 0 0	Oct. 31	Letter No. 1.
Feb. 28	"	"	" 2.
Mar. 31	"	"	" 3.
Apl. 30	"	"	Special letter, threatening legal proceedings.
May 7			Cash received in settlement.

Receipts. Receipts should be issued for all cash or cheques. Many firms acknowledge receipt on the bill or statement, but it is far better to use a carbon copy book of printed receipt forms, numbered consecutively. This minimises fraud and serves as a basis for entering up the Cash Book.



FINIAL. Fig. 1. Type of finial used on lead dome.

FINIAL. The ornamental piece of leadwork used to cap and complete a slated, lead or copper-covered spire or turret. The usual type is composed of a small sphere supported by a graceful stem, relieved, if necessary, with other members and completed on a proportionate base (Fig. 1).

The finial may be covered in one or two pieces. It is not wise to attempt to boss very large pieces; though this shows a

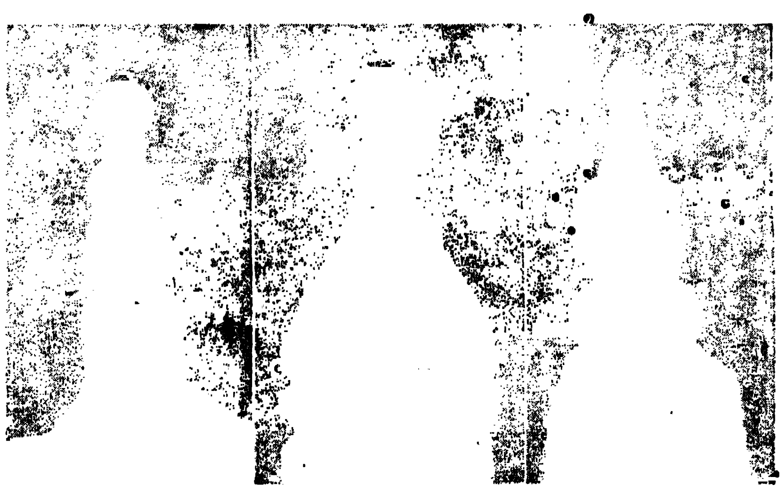


Fig. 2. Finials covered in one piece of lead: (left), base a square pyramid, upper portion circular, overall height 2 ft.; (centre), removed from octagonal turret, lead at base worked over rolls of turret to form overcloaks, overall height 2 ft. 4 in.; (right), base a deep square with bevelled corners, and upper part circular; overall height 3 ft. 9 in.

considerable amount of skill, it involves wasted labour when a large finial is covered in one piece of lead without jointing. There is no reason why a finial should not be covered in two or more pieces, provided the laps are arranged in such a position as to be weathered. The finial may be hollow, loaded with plaster, or be worked on to a solid wood former.

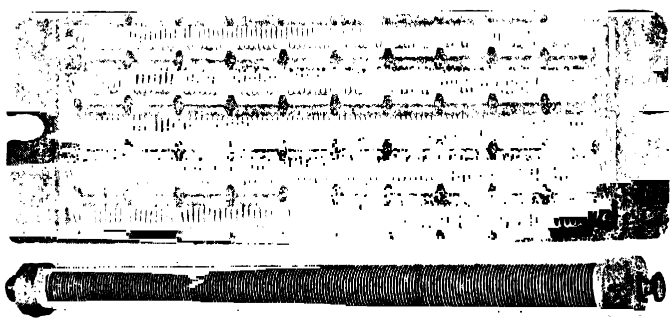
If it is desired to use more than one piece of lead, care must be taken to start at the base, the piece being worked or clipped in position. The stem may be composed of a piece of solid drawn lead pipe, and the whole can then be completed with a suitably worked lead sphere. In working the various members, or in working the finial in one piece, see that the piece of lead used is not of a greater area than required, or much labour will be wasted on the surplus lead which is trimmed off. If the piece is too small, a great deal of stretching will have to be done in the attempt to get a good fit, and very often this results in a fracture appearing. A rough idea must be obtained of the lead required to work the finial; this may easily be arrived at by finding the approximate surface area of each member.

Working a Finial. The lead should first of all be bossed to the form of a saucer or basin before it is placed in position; after this shape has been obtained, the lead should be placed over a mandrel end and again bossed until it is the right size to fit over the largest member of the finial. Great care must be taken to draw out the lead evenly rather than to stretch it, or a fracture will result. The lead should now be placed in position over the finial core, and further worked in until the correct shape is reached.—*J. Malpass, M.R.San.I.*

See Leadwork, Ornamental.

FIRE : Electric. An electrical heating apparatus in which the heating element is operated at a bright red heat; designed to replace or supplement the coal fire, though not necessarily to imitate it. For domestic purposes the electric fire is probably more widely used at the present time than any other form of electrical heating apparatus. A high proportion of the heat from an electric fire is emitted in the form of radiant heat; radiant heat cannot warm the air in a room directly, but only after it has heated the objects in its path.

The chief advantage of the electric fire is that anyone standing in front of it experiences a sensation of warmth almost immediately it is switched on. But unless a supplementary form of heating is used (*see* below) there is the danger that parts of the body facing the fire become overheated while the rest of the body is still feeling chilly (especially in a fair-sized room) because the temperature of the air and walls is still low. Therefore, when



FIRE : Electric. Fig. 1 (top). Fire-bar type element on curved panel; coils of special heat-resisting alloy, mounted in diffusive reflectors. Fig. 2 (bottom). Rod-type element coiled round steatite rod, to be placed in front of metal reflector.
General Electric Co., Ltd.

electric fires afford the sole source of heat they are best used for bedrooms, bathrooms, and other rooms only occupied occasionally. In a bathroom, of course, the fire is a fixture inset into the wall high up out of reach of the users. In living rooms, except the smallest, electric fires are most satisfactory as a means of supplementary heating in conjunction with convectors or some other form of low-temperature heating. (*See* Heating : 4.)

Portable fires should not be placed in front of unblocked chimney openings to avoid loss of heat. Inset fires are very neat, but in smaller property careful thought must be given to positioning to avoid undue limitation on placing of furniture.

Elements. Two main types of elements are used for electric fires : the fire-bar and the rod type. In the first, coils of special heat-resisting alloy are mounted on the face of a steatite or fireclay former in specially designed troughs which act

as diffusive reflectors. In the second the wire is coiled round a steatite rod. If properly handled, elements seldom burn out, but if they do they should be replaced as a whole.

The fire-bar type is sometimes, and the rod type invariably, placed in front of a metal reflector. A plain reflector is used to produce a concentrated beam, and a dimpled reflector for a more diffusive beam.

Loading. The loading of a fire as a sole source of heat should be approximately $1\frac{1}{2}$ watts per cu. ft. As fires are obtainable having 1, 2, and 3 elements with separate switching, it is advisable to choose one with a loading in excess of the actual needs so that the desired temperature may be reached as rapidly as possible, after which some of the elements can be switched off. The rated voltage of the fire should be as near to the supply voltage as possible; too high a voltage will rapidly lead to a burn out, too low a voltage to a loss of efficiency.—*R. A. Baynton, B.Sc.*

See further under Heating: (4) By Electricity.

FIRE: Gas. For full details of gas fires, air-heaters, "radiators," and other associated methods of heating by gas, *see under* the heading Gas Fires; *see also* Heating: (5) By Gas.

FIRE RISKS: In Plumbing Work. Fire risks occasioned by plumbing work should be guarded against. Invariably, with houses built under an architect's supervision, a clause is inserted in the contract that the building shall be insured in the joint names of owner and building contractor against this or other risks. This clause, although satisfactory to the parties concerned, may create complications if plumbing work is carried out under a sub-contract; the employer sub-contractor, if fire should occur through the negligence of his employees, may have to rebut a claim to recover damages.

Insurance companies will add a covering clause to the employer sub-contractor's policy for a very small percentage, to give him complete immunity against such a claim; the basis usually taken is on wages paid per annum.

Fire Dangers. The dangers that exist are easily appreciated when one is conversant with practice: a petrol blowlamp may explode; a paraffin type blowlamp may throw a jet of liquid oil instead of vapour, which may ignite rafters or other timber; a man may be working in a confined space with a naked light and leave this for a few moments without thought, and the light may fall over or otherwise come in contact with combustible material. Numerous other cases could be mentioned. Such everyday actions of an employee are an employer's responsibility, and apparent negligence does occur when a fire is caused. Claims may be made by owners of premises, and this risk should be adequately covered.

In carrying out electrical work, gas pipes must not be used as electrical earths.

Many of the risks encountered are due to the fact that work is being carried on in an uncompleted building, with the litter left about by other tradesmen, and probably no water supply on the upper floors. Thus a lighted match or cigarette end may cause the ignition of shavings below or round about, and in a few moments a conflagration is started that may be difficult to put out unless taken in hand with great promptitude.

Work being done on wood roofs demands vigilance from the plumber. Lead-burning on flats calls for the protection of the underlying woodwork by an asbestos sheet or other fire-resisting material.

Safeguards. In work where the risk is considerably increased (such as in a confined roof space, or when pipe lines run through timber surrounds), protection should be provided by shielding with sheet asbestos. A bucket of water or sand should be placed handy in readiness.

Precautions are needed when a felt-lined timber roof is being perforated for various pipes, such as ventilating and overflow pipes. Certain work is carried out for external weathering of these pipes: see that the felt is cleared well back before fitting the lead slate; this applies especially to lead pipes, which would need a solder flange joint.

It often happens that boilers have to be fitted into existing houses that are being reconstructed. In these cases an existing flue may be used, and the worker must make sure that no trimming joist is taking a bearing on the chimney brickwork. This is not likely with recently built houses, but has been known to happen in old construction. The end of a joist so fixed would eventually catch fire and set light to the whole building.—*R. J. Audrey, M.R.San.*

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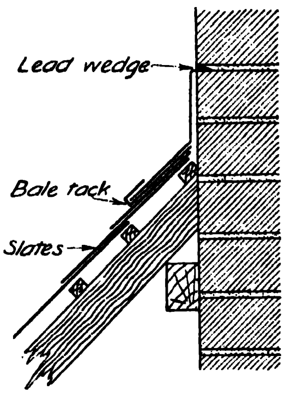
FLASHINGS: (1) IN LEADWORK

By T. Jennings, M.R.San.I., R.P.

This contribution describes the functions and uses of flashings, and deals with the various types. Instructions are given for the practical work of marking out, preparing and fixing. The numerous diagrams show clearly how the work should be carried out. Flashings in Copper are dealt with in the article immediately following. See Chimney; Roofwork: (I) In lead; Tack.

Flashing in leadwork is fixed wherever a slated, tiled or lead-covered roof abuts against a vertical wall, or where any part of the erection penetrates the roof. The upstand, or free edge, of any piece of roof leadwork, if not covered by the roof slates, must be protected by a cover or flashing to prevent water running between the lead and brickwork and penetrating into the building.

Terms. The accepted terms for different kinds of flashing are employed in this article, but in various parts of the country other names are used. Thus *string flashing* and *skeleton flashing* refer to *hanging strip* or *sawtooth flashing*, as illustrated in Fig. 10. *Step-and-cover flashing* is the same as *cover-and-apron flashing* (*see* Figs. 4 and 5). *Cap flashing* and *overflashing* denote one and the same thing and refer to any piece of *cover flashing*.



FLASHINGS: LEADWORK Fig. 1. Apron flashing, self-flashed, between vertical wall and lean-to slated roof, tucked into joint at top and held by "bale tack" at bottom.

The most common instances where flashings are used are the junctions of roofs and chimney stacks; dormer windows; roof-lights; vent pipes passing through roofs (in which case a lead slate is used); roof abutting against wall; break in line of roof; as well as any projection from the face of the building, such as door-hoods, bay windows, etc. In fact, any junction between slates or tiles and brickwork is invariably made weathertight by means of a lead flashing.

Except in a very few instances, this flashing, or cover to the upstand of the lead against the brickwork, is a separate piece of lead so shaped and fixed as to form a loose but weathertight joint between the two and at the same time to allow the lead to expand and contract with freedom.

Flashings may be divided into two types, which will be considered in detail:

1. Apron Flashings: combined cover and apron in one piece, serving a dual purpose. Sometimes described as being "self-flashed."

2. Cover Flashings: cover flashing only (*e.g.* oversoaker), which is fixed in brick joint and turned over upstand of lead.

Apron Flashing. Fig. 1 shows flashing between vertical wall and lean-to slated roof. Top turned into joint ¾ in. and bottom edge supported by "bale tack" (*i.e.* strips of lead 2 in. wide secured to slate lath and turned up over bottom of apron). The height of vertical part will vary with the height of joint above, and the depth of apron lying on slates will vary with the distance that lap of slates is from brickwork, and is usually 6 in. to 8 in. deep.

Fig. 2 shows apron flashing fixed to window sill and turned down tiles. It is fixed under sill before uprights are fixed and turned up inside and nailed. Flashings can sometimes be nailed on to the window frame, set upside down, before frame is fixed in position. Fig. 3 is another example of horizontal apron

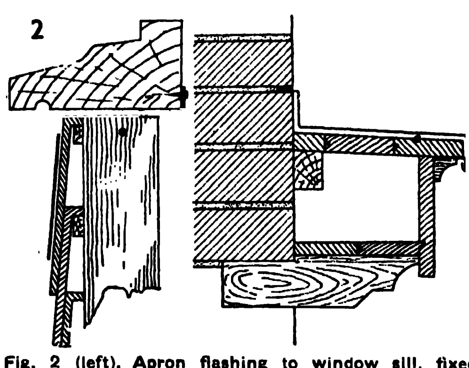


Fig. 2 (left). Apron flashing to window sill, fixed under sill and turned down tiles. Fig. 3. Horizontal self-flashed apron fixed to wood door-hood or narrow cornice to shop front.

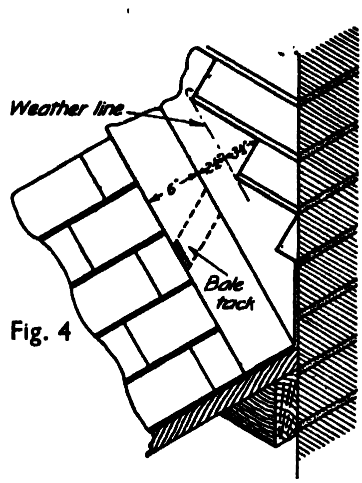


Fig. 4

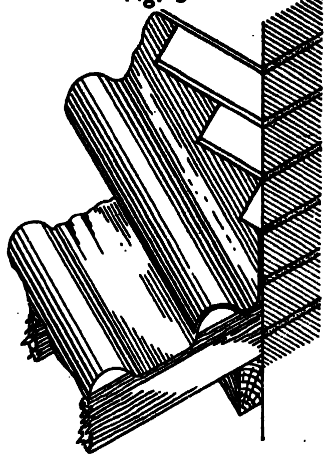
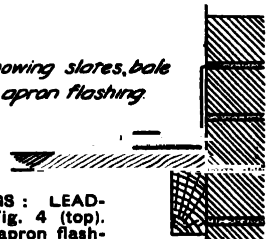


Fig. 5

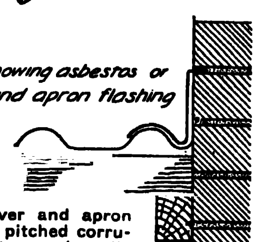
Section showing slates, bale tack and apron flashing.

4A



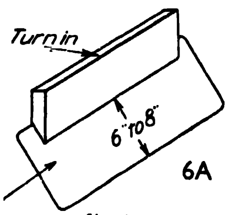
Section showing asbestos or clay tile and apron flashing

5A



FLASHINGS : LEADWORK. Fig. 4 (top). Cover and apron flashing to pitched slate roof and vertical brickwork, showing weather line, dimensions, and bale tack. Fig. 4a. Section through roof, flashing and brickwork, showing turn-in at top and tack under apron.

Fig. 5. Cover and apron flashing to pitched corrugated asbestos or clay tile roof and vertical brickwork. Fig. 5a. Section through Fig. 5.



6A

Front apron flashing ready for fixing.

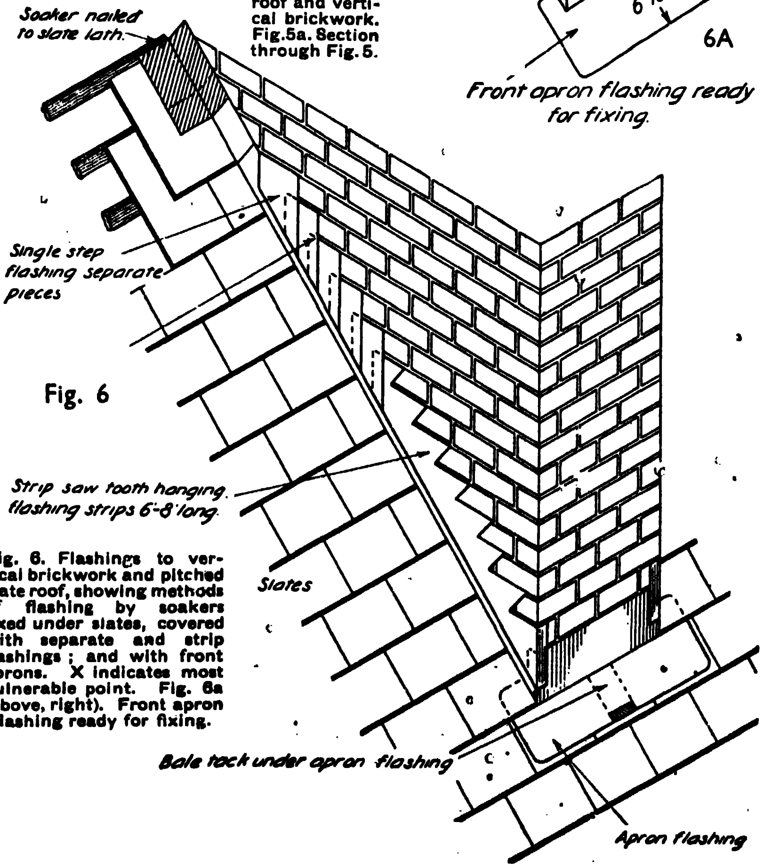


Fig. 6

Fig. 6. Flashings to vertical brickwork and pitched slate roof, showing methods of flashing by soakers fixed under slates, covered with separate and strip flashings ; and with front aprons. X indicates most vulnerable point. Fig. 6a (above, right). Front apron flashing ready for fixing.

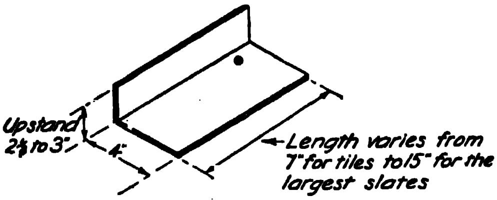
flashing, fixed to wood door-hood or narrow cornice to shop front. The front apron flashing shown in Fig. 6 is yet another example: the prepared piece, ready for fixing, is shown in Fig. 6a.

In Fig. 4 is seen cover and apron flashing to "pitched" slate roof and vertical brickwork. The lead is 12 in. wide (6 in. apron lying on slates, the other 6 in. upstand against wall). Bale tacks should be fixed under apron. Fig. 4a shows section through flashing.

Cover and apron flashing to "pitched" corrugated asbestos, interlocking or Roman type of clay tile roof and vertical brickwork is shown in Fig. 5. The same flashing could be applied to the old or new type of "pantile" roof. Fig. 5a shows section through flashing.

Cover Flashing. The second type of flashing involves the use of "soakers"

(Fig. 7), which are fixed under the tiles or slates, and replace the apron which in the other type lies on top. Soakers are pieces



FLASHINGS : LEADWORK. Fig. 7. Soaker, to be fixed under tiles or slates and under cover flashing (see *also* Figs. 6, 10a, 13, 15) ; best method of weathering slated or tiled roofs.

of 3 lb. or 4 lb. sheet lead, cut to lengths varying from 7 in. for tiles to 15 in. for large slates and 6 in. wide, to go under slate, with an upstand of 2½ in. to 3 in. Soakers are usually made by the plumber, but fixed by the slater.

With the introduction of these soakers the flashing has now a single purpose and, therefore, is termed a "cover" flashing. Cover flashing and soakers form the neatest and best method of weathering slated or tiled roofs.

There are two methods of fixing : *Single Step Flashing* (Fig. 8). Generally considered the best method, although the most expensive as regards the amount of lead used, through overlapping. They afford protection at the most vulnerable point (X, Fig. 6) by enabling the under step to be properly pointed in joint. Fig. 9 illustrates how they can be cut out of a strip or rectangular piece of sheet lead without waste, the pitch and width varying with the angle or pitch of the roof.

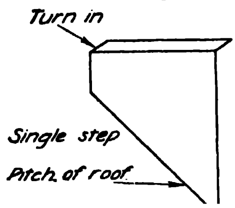


Fig. 8. Single step flashing, best method of protecting most vulnerable point of weathering.

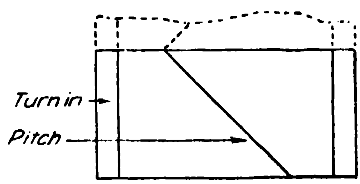


Fig. 9. Method of cutting single step flashing from sheet with economy, the angle of the roof controlling the pitch and width of the cut piece.

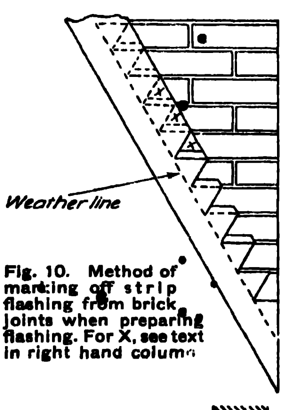


Fig. 10. Method of marking off strip flashing from brick joints when preparing flashing. For X, see text in right hand column.

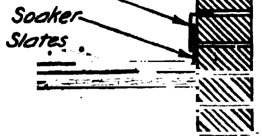


Fig. 10a. Section through Fig. 10, showing relative positions of cover flashing, soaker, and slates (compare Fig. 4a).

Hanging Strip or *Saw-Tooth Flashing* is the next best, which makes a very neat job, especially on steep roofs, and is less liable to be blown away from wall by the wind (which often occurs with single step flashings unless secured at the bottom points). It can be fixed in any length up to 7 or 8 ft., and is usually cut off 6 in. wide.

If the brickwork is "gauged" it may be possible to mark off and cut out the strip before taking up on to the roof, but it is usually found advisable to prepare and fit as follows :

Preparing and Fitting Flashing. Mark a line 2½ in. from one edge, known as the weather or water line, place strip on roof in the proposed position, and with a straight-edge mark horizontal lines (corresponding with each brick joint) from the outside edge to the weather line. Next lay flat on board, and mark off and cut a line from weather line to end of line of joint above. This gives the bevelled cut or overhanging part. Next mark a line ¾ in. from the horizontal line and cut out the small triangular piece, as marked X, Fig. 10. By means of a step folder (Fig. 11a) turn this ¾-in. strip over either right or left hand for turning into brick joint. Fig. 11 shows part of the strip turned ready for fixing.

All the small triangular pieces are waste. In many cases this wastage can be saved by adopting another method of cutting the strips, with their serrated edges inter-

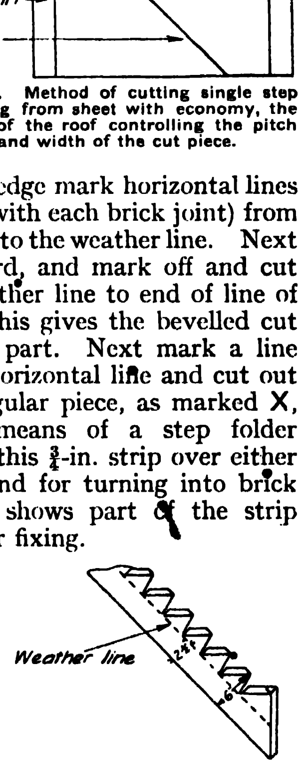
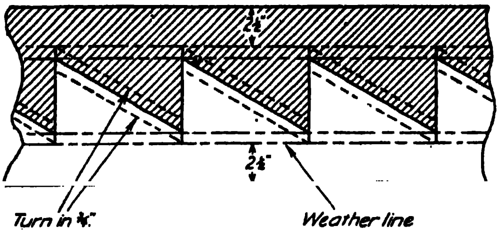


Fig. 11. Part of strip flashing bent ready for fixing.

Fig. 11a. Step folder used for turning lead strip marked out as in Fig. 10.



FLASHINGS : LEADWORK. Fig. 12. Economical method of cutting strip step flashing, from one strip 10 in. to 12 in. wide, according to pitch ; cuts shown by firm lines, folds by dotted. Two strips are obtained, one is shown shaded.

locked, as shown in Fig. 12. This method is very economical, and is particularly suitable for repetition work. In preparing this type it will be found much quicker to cut a pattern in zinc or even "damp-course felt" and then mark off the strip. Fig. 12 shows the two pieces interlocked, one being shaded and the other clear. It will also be seen that the two 6-in. pieces can be obtained from a

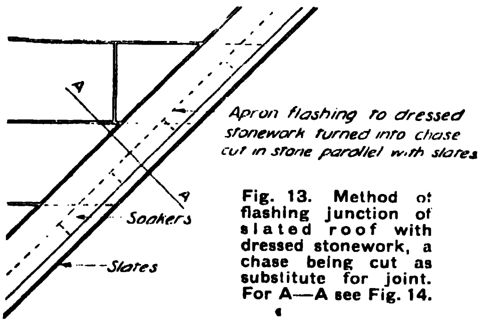


Fig. 13. Method of flashing junction of slated roof with dressed stonework, a chase being cut as substitute for joint. For A—A see Fig. 14.

narrower strip (10 in. to 11½ in. wide, according to the pitch of the roof).

Slated Roofs. Methods applicable to slated roofs are shown in Figs. 13–15. The first and second illustrate method of flashing the junction of a slated roof with dressed stonework. In this case the joints are too far apart to be made use of, so a chase or groove is cut in the stone (as shown in section, Fig. 14) parallel with the slates, and a strip of lead is prepared and fixed in this chase as a cover flashing. If this flashing is wide, bale tacks may be used with advantage, turned over the top of soaker and the bottom edge of flashing (see Fig. 14).

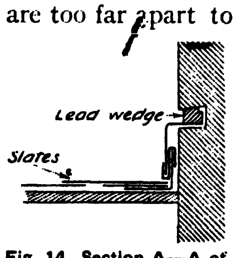


Fig. 14. Section A—A of Fig. 13, showing lead wedge, flashing, soaker, bale tacks, and slates.

In Fig. 15 is indicated the method employed to flash the junction of a slated roof with a random rubble wall. A cover flashing has to be fitted and fixed to the nearest joint parallel to the slates. It is very seldom that these flashings can be fixed in long lengths.

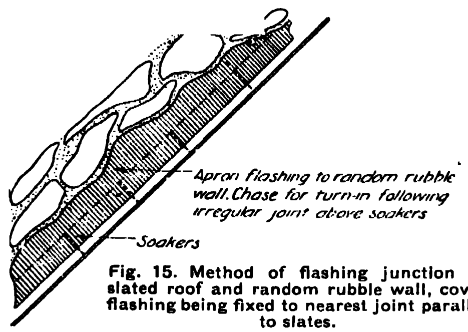


Fig. 15. Method of flashing junction of slated roof and random rubble wall, cover flashing being fixed to nearest joint parallel to slates.

Concrete and Asphalt Roofs. Examples of flashings for each of these are given. An apron flashing fixed to edge of concrete roof is seen in Fig. 16, the lead being laid on shuttering before concrete is laid. Fig. 17 shows a similar apron strip laid on wood roof covered with felt and asphalt.

The essential principles of flashing have

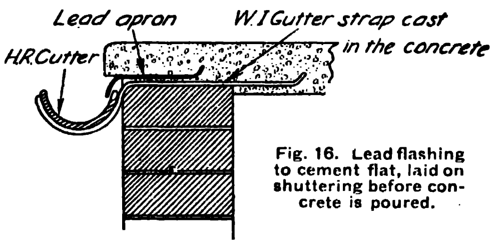


Fig. 16. Lead flashing to cement flat, laid on shuttering before concrete is poured.

been explained in the preceding pages, and basic methods described. Parallel information is given also in certain other articles throughout this work, as for example: Apron; Chimney; Dormer; Lantern Light; Roofwork.

The subject of Flashings in Copper is treated in the next article, but since many of the methods are identical with those for lead, the basic instructions here given are not repeated under Copper.

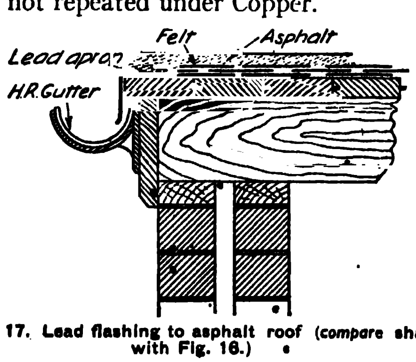


Fig. 17. Lead flashing to asphalt roof (compare shape with Fig. 16.)

FLASHINGS: (2) IN COPPER

By E. Carr, Ph.D., B.Sc., M.I.P.

Building Engineer, The Copper Development Association

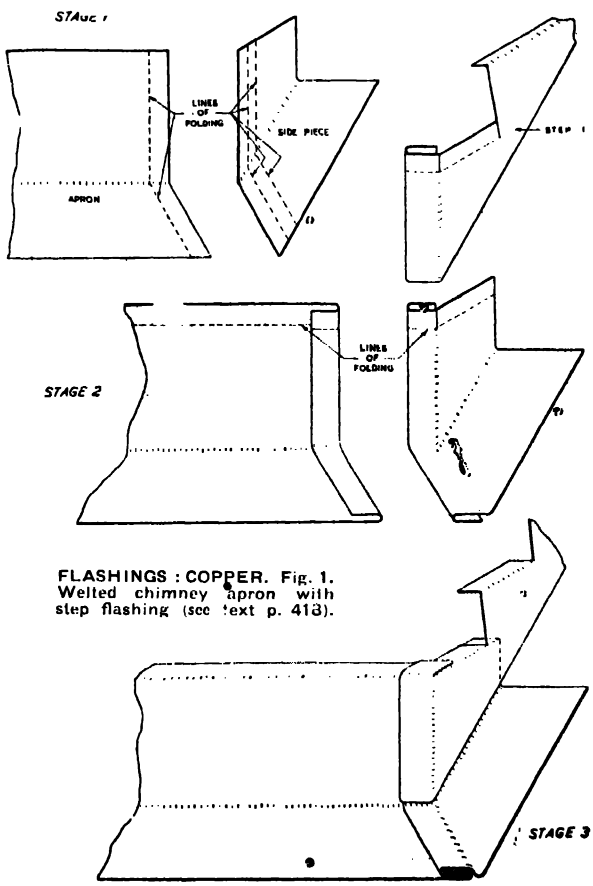
The general principles and design of Flashings are discussed in the preceding article on lead flashings. The present article therefore deals with those points in which copper calls for different treatment. See *also* Roofwork in Copper.

The use of copper sheet for flashings, in association with copper roofing, has always been accepted as standard practice. Its use, however, for flashings and other details of external plumbing in conjunction with roof coverings of slates, tiles, asphalt and the many patent roofing materials, has until recently been small compared with the widespread use for these purposes in America and the Scandinavian countries. The very competitive price of the metal in thicknesses used for flashings has led to an increase in its use in all types of buildings. Metal for metal, 24 S.W.G. copper is generally considerably cheaper than 5 lb. lead.

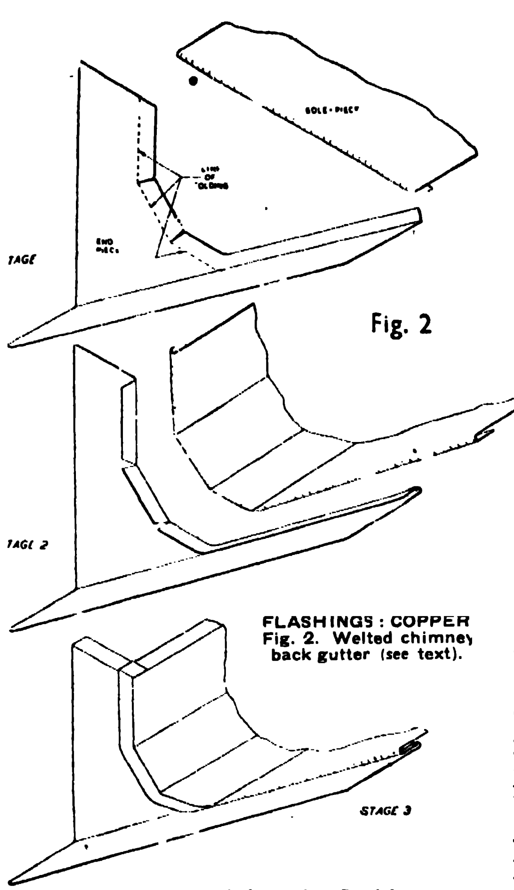
Owing to its resistance to corrosion, its lightness, strength, and absence of creep, copper sheet or strip is an ideal material for flashings and weatherings of any description. Moreover, when in contact with Portland cement or lime mortar, no action detrimental to the metal takes place. In some of these respects it may be considered superior to lead, and in its soft temper it is ductile and easily worked. Whilst it is not so malleable as lead, the technique of sheet copper working enables it to be moulded to the more general contours encountered in building, such as the curves of pantiles; for all straightforward flashings its working presents no difficulties, and much of the preliminary manipulation can be done with the hands only.

The strength of copper used for flashings is usually of 24 or 26 S.W.G. thickness and must be of dead soft temper. Standard sized sheets are 4 ft. × 2 ft., 6 ft. × 3 ft., and 8 ft. × 4 ft. These are generally manufactured by hot rolling. In addition, cold rolled strip up to 24 in. wide and in lengths of up to 150 ft. are also available, and, generally speaking, strip is cheaper than sheet of the same thickness. The advantages of using copper strip are obvious. For instance, a long cover flashing over the upstand of a parapet gutter, particularly if the flashing is carried through the parapet to form a damp-proof course, is a case where strip could most usefully be employed. Cold-rolled strip must always be specified to be fully annealed, or in dead soft temper. A new British Standard for copper sheet and strip for building purposes was due to be issued in 1949.

Joints in Flashings. The general principles and arrangement of copper flashings are similar to those of lead. Slight differences are due principally to the fact that 24 S.W.G. copper, whilst stronger, is lighter, thinner and harder than 5 or 6 lb. lead.



FLASHINGS : COPPER. Fig. 1. Welted chimney apron with step flashing (see text p. 418).



FLASHINGS : COPPER Fig. 2. Welted chimney back gutter (see text).

For this reason, joints in flashings are generally made with welts rather than by overlapping. The comparative thinness of the metal allows welted joints to be made very neatly and, moreover, they provide an unbroken protection against penetration by moisture. For instance, in the making of a ***Chimney Apron*** it is not an economical proposition to attempt to dress the metal to form a return, and a separate piece is cut and welted to the face part of the apron, to form these angles (Fig. 1).

Note that the welt on the roof slope is placed at a diagonal ; this greatly facilitates the making of the welt. The side piece and apron-end are first bent, marked, and cut to shape as shown in Stage 1. They are then straightened out into flat sheets again and a ½ in. half-lock welt is formed on each, the apron upwards and the side piece downwards. Both pieces are now bent to the required angles (as Stage 2) and all that remains to be carried out is the final welting. Concentrate on first assembling the point where the two bends are and then fasten the vertical welt, pull the diagonal half welts into position, and welt the pieces firmly together. With a ball-pane hammer the lower portion of the vertical welt may now be dressed back.

All free edges, such as raking edges of stepped flashings, and lower edges of hanging flashings should be turned back on themselves to form a narrow bead for added thickness.

Back Gutter. It is advisable to have a 45° angle fillet of timber between the brickwork and the base of the gutter to facilitate working down the welt. Fig. 2, Stage 1, shows the end piece bent and cut to shape. The edge to form a half welt is cut in two pieces, but not the third, the latter being the point where the roof slope meets the base of the gutter. The half welt is formed on the sole piece while still a flat sheet, then bent to shape as Stage 2. Stage 3 shows the finished joint and the welt dressed down to the chimney side. Avoid making sharp bends until the welting is completed.

Soakers, Tacks, etc. Copper soakers are cut from 24 or 26 S.W.G. sheet or strip and then bent in the same way as those of lead. Stepped cover flashings can be formed in a continuous piece or in separate units.

Tacks, or cleats, are often not necessary with apron flashings, but for an apron longer than 2 ft. 6 in. cleats or tacks are fixed to secure the free edge and prevent it lifting.

In certain cases, for instance, on a dormer cheek, the top edge of the soakers, forming the upstand, can be welted to the free edge to secure a weathertight joint, unless a lap of a minimum of 2 in. is pos-

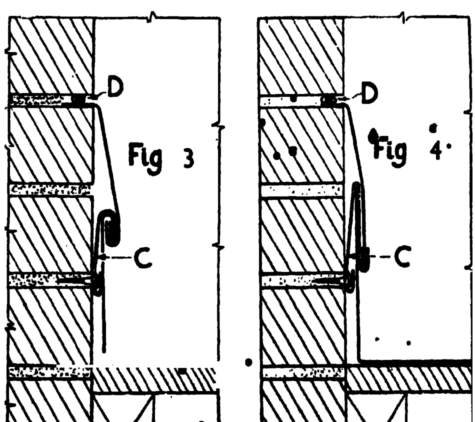
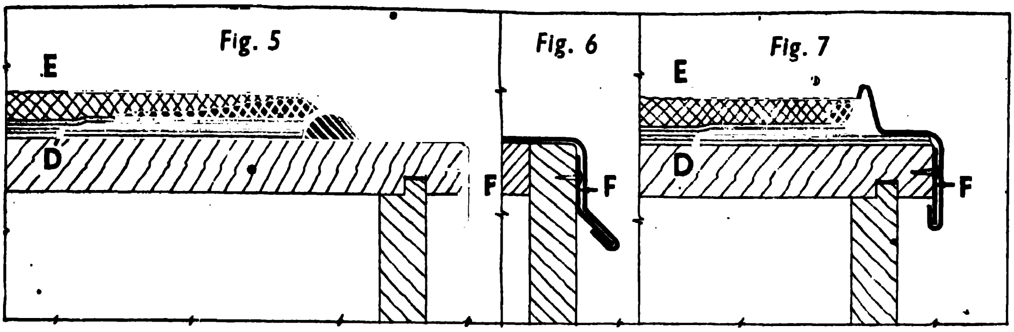


Fig. 3. Cover flashing welted to upstand. Fig. 4 Hanging flashing, lower edge doubled under fo stiffness. C, tacks ; D, wedges.



FLASHINGS: COPPER. Figs. 5-7. Copper aprons at edges of flat roofs: (5), copper laid over half-round bead, which acts as stop to roofing, and turned over to form drip; (6), alternative drip to that shown in Fig. 5; (7), stop to roofing formed by double upstand in copper apron: suitable for roof edges at top and sides of fall; D, layers of felt and bitumen; E, top dressing of macadam or gravel; F, lining strips.

sible, in which case the free edge of the sheet covering the dormer check is held by copper cleats. Wedges for fixing flashings in brick joints are made by rolling up small pieces of copper sheet. (Figs. 3 and 4.)

Flashings to Flat Roofs. Copper is much used in the flashing of flat roofs of asphalt, or laminated roofing of bitumen, felt and gravel, both for the protection of the junction of the roof with vertical walling or chimneys and for the apron flashings or drips at the edges. For the latter, the copper may be laid over a half-round bead to form a stop for the roofing (Fig. 5); or at the sides of the roof a stop for the top dressing of macadam or gravel may be formed in the copper itself, by means of a doubled upstand, since the metal, after bending, is sufficiently stiff for this purpose (Fig. 7).

The upstand should be placed a little back from the edge of the roof to avoid damage by ladders. In the best practice, a lining strip fixed to the fascia or edge of the roof is used to hold down the outside edge of the copper apron which is doubled round it. The lining strip also serves to keep the drip straight and neat in appearance. This is illustrated in Figs. 5–7.

Any apron flashings which overhang vertical masonry or light-coloured brickwork should be finished with a drip well clear of the vertical surface, in order to avoid any staining by the wash from the copper during the initial period when a patina is being formed.

Flashings to Weatherings. Copper flashings may also be required in conjunction with weatherings of copper. Stone, concrete or wood cornices, canopies and string courses are often covered with copper sheet, and when these project from vertical walling the sheet copper is turned up against the wall and welted to a flashing which is fixed into a joint in the brickwork or, where necessary, a groove cut in the masonry, with rolled copper wedges as already described for flashings to chimneys, etc.

Coverings for narrow horizontal ledges or projections can be turned up and fixed straight into the brick joint without a separate cover flashing, providing there is sufficient fixing at the front edge, for instance with a lining strip as indicated in Figs. 5–7.

Flashings to copper-covered pediments are stepped in the usual way. Where copper is used for the weathering of wood or stone cornices, and a gutter is formed in the cornice at the foot of a tiled or slated roof, it is usual to finish the junction of the gutter with the roof with a separate flashing, which is taken up over the tilting fillet and welted to the upstand from the gutter on the front face of the fillet.

Copper Flashings in Timber Construction. In conjunction with timber construction, copper cover flashings to soakers, etc., where tiled or slated roofs abut timber walls finished with weather-boarding or lath and plaster, are taken up behind the weather-boarding or plaster and copper nailed to the timber studding.

Horizontal flashings to drip boards over windows and doors are taken up behind the weather-boarding or plaster in the same way. Where external plaster is finished over copper flashings, either on the slope or horizontally, a good key for the bottom inches of plaster can be obtained by means of expanded metal lathing which is fixed to hang down over the copper.

FLATS: PLUMBING, SANITATION, HOT WATER SUPPLY

By F. C. Cook, M.R.San.I.

Dealing with Flats as they concern primarily the plumber, heating and ventilating engineer. The first section is devoted to working-class flats, and gives information on hot water supply, wastes, soil pipe arrangements, etc. In the second section Flats of a more expensive class are dealt with, notes being given on planning of fitments. The final section discusses water-closet arrangements, with special reference to the use of mechanical ventilation. Relevant by-laws are quoted throughout. See Bath and Bathroom; Building Construction; One-Pipe System; *also* Acts and By-Laws; London County Council By-Laws.

Of recent years flats have become very popular both in London and in provincial towns. The shortage of housing accommodation in the years following the Great War was responsible for the Government subsidizing housing schemes, not only for private concerns but also those taken up by local and county authorities. This concession was instrumental in abolishing many slum areas in large towns, which were superseded by the installation of blocks of working-class self-contained flats. In practically all cases the tenants had known nothing better than sharing a house with one or more families—an arrangement where privacy behind one's own door was unknown—and the amenities regarding sanitary accommodation were in a very meagre form, usually consisting of one water-closet in the yard and either a tap over the yard gully or a small sink and tap on the stairway for the general use of all occupants.

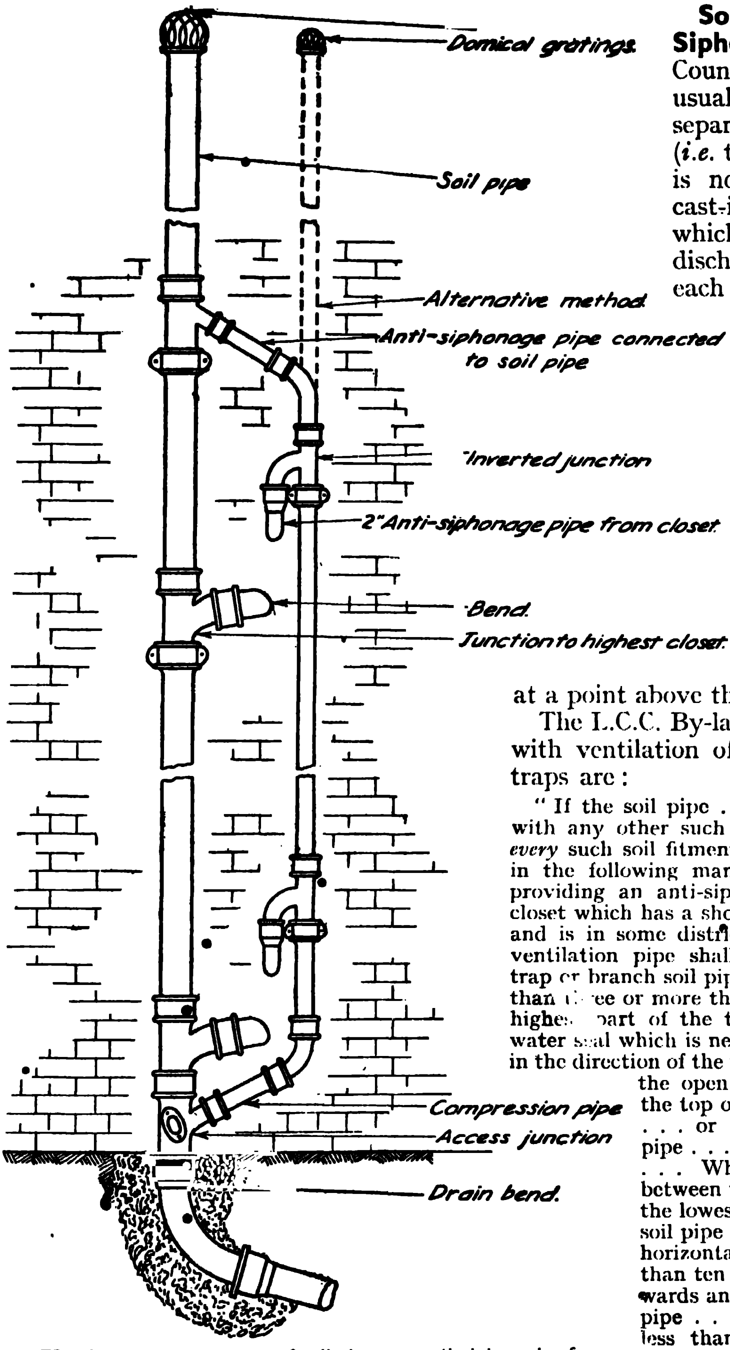
In the larger towns the question of overcrowding was one in which the local authorities were powerless, seeing that a Court order could not be put into effect where there was no alternative accommodation available. It must be remembered that during the War years no new housing accommodation was erected, while general dilapidation was accelerated by the lack of maintenance; some houses fell into a state of decay and were rendered dangerous. It was due to the fact that this condition was general (so far as the lower wage-earners' accommodation was concerned) that such rapid strides were made in constructing houses on the outskirts and working-class flats in towns. The cost of land in most towns does not permit the erection of separate houses for this class of tenant; therefore, to make the scheme an economic proposition, a number of accommodations are installed above each other, and we get flats.

A. WORKING-CLASS FLATS

The general amenities of modern working-class flats usually comprise one to four bedrooms, living room, scullery, bathroom, separate water-closet, ventilated food cupboard, coal bunker, proper cooking facilities and ample cupboard storage. In some cases perambulator storage and a communal laundry are provided.

Hot Water Supply. Hot water for the bath (*see* Bath) is usually provided in conjunction with a gas-heated copper situated in the scullery adjacent to the bathroom; the hot water supply is obtained by water displacement (*i.e.* cold water enters the copper at the bottom and so displaces the hot water above, which overflows through a pipe into the bath), or a small pump is installed where this principle is impracticable. The writer was concerned with a scheme for supplying six blocks of this class of flat with constant hot water on the calorifier principle from a central boiler. A 4-in. " primary flow " pipe from the boiler entered a 2-ft. brick-constructed duct which passed under the ground floor of each block in turn, while the " primary return " pipe was attached to an accelerator pump before returning to the boiler. In each of the sculleries a 25-gallon galvanized hot water tank was installed in which there was a coil of pipes connected with a vertical secondary flow and return pipe, the central boiler thus supplying heat to the coil. The hot water tank was supplied with cold water from the storage cistern in the roof; this water became heated by contact with the heated coil within the tank. The draw-off taken from the top of the tank was connected to the bath and sink; therefore the hottest water was always available.

In the general lay-out of these flats, so far as the plumbing work is concerned,



FLATS. Fig. 1. Arrangement of soil pipe an . nti-siphon pipe for a block of flats : 4-in. c.i. soil pipe receiving closet discharge on each floor ; 2-in. anti-siphon pipe connected to soil pipe below last junction and above highest, or carried up as shown by dotted line ; ventilation of soil pipe and closet traps by anti-siphon pipe and open-air vent as regulated by by-laws (see text).

it is usual to arrange the water fitments in close proximity to each other, as these recur on each fl... r, one group immediately above the other.

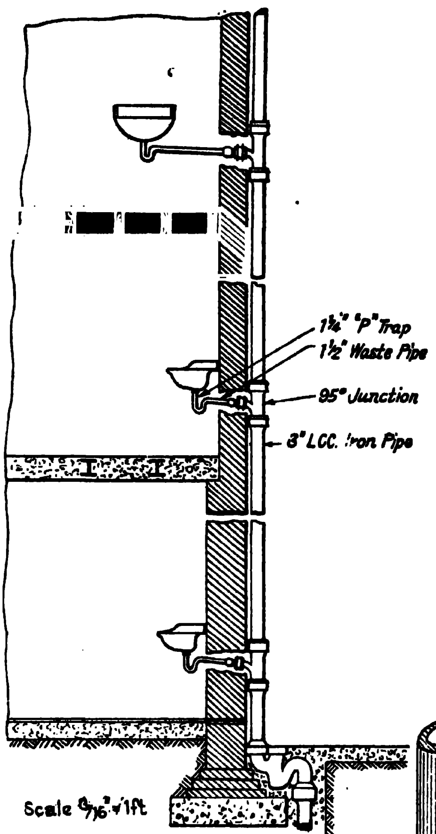
Soil Pipe and Anti-Siphon Pipe. With London County Council flats it is usual for the soil pipe to be separate from the waste pipe (*i.e.* the " one-pipe " system is not adopted). A 4-in. cast-iron soil pipe is installed which receives the closet discharge into a junction on each floor, while a 2-in. lead or cast-iron anti-siphonage pipe is connected to the stack below the last junction, and with 2-in. branches connected to each closet junction. The termination of the anti-siphonage stack can be treated similarly to the soil ventilation pipe, or it can be connected to the latter at a point above the top junction (Fig. 1).

The L.C.C. By-law requirements dealing with ventilation of soil pipes and closet traps are :

" If the soil pipe . . . shall be in connexion with any other such fitment . . . the trap of *every* such soil fitment . . . shall be ventilated in the following manner." [The necessity of providing an anti-siphonage pipe to the top closet which has a short branch is questionable, and is in some districts omitted.] " The trap ventilation pipe shall be connected with the trap or branch soil pipe . . . at a point not less than t.. ee or more than twelve inches from the highe.. part of the trap, on that side of the water seal which is nearest to the soil pipe . . . in the direction of the flow ; . . . be carried into the open air to a point as high as the top of the soil ventilating pipe . . . or into the soil ventilating pipe . . . above the highest fitment. . . . Where the vertical distance between the invert of the outlet of the lowest trap connected with the soil pipe . . . and the invert of any horizontal pipe or drain . . . is less than ten feet, be continued downwards and connected with the soil pipe . . . or drain at a point not less than nine inches and more than two feet below the invert of the lowest branch soil pipe (. . . or a manhole in the line of such drain)." *See* Fig. 1.

The same requirements are enforceable on the " one-pipe " system.

Bath and Sink Waste. With regard to the bath and sink wastes, in L.C.C. flats the fitments are so arranged that the



FLATS. Fig. 2. Bath and sink waste: fitments are connected to the 3-in. c.i. stack by P-traps and 1½-in. galvanized w.i. waste; main stack discharges into gully trap; no anti-siphon pipe here required by L.C.C. By-laws.

branch wastes are short, being not more than 4 ft., and discharge into a 3-in. cast-iron stack by means of a 1½-in. diameter and 1½-in. seal P-trap connected to a 1½-in. galvanized wrought-iron waste pipe, lead caulked into a 95 deg. cast-iron junction; no anti-siphonage pipe is installed, although there are washing fitments discharging into the same stack on each of the succeeding floors. Although this procedure is not generally recognized, it is provided for in the L.C.C. By-laws where the fitments discharge into a gully trap via the main waste stack, but not when connected to a stack which is connected direct to the drain. The section dealing with ventilation of traps of waste-water fitments states that:

> "In order to preserve the seal of the trap of any such fitment, such trap shall be ventilated *whenever necessary* by a ventilating pipe carried to such a position as to prevent any nuisance . . . arising from the emission of foul air from such pipe . . ."

The requirement is, therefore, that a ventilation pipe shall be installed for the purpose of maintaining the seal of the trap whenever necessary.

With the conditions as stated, no siphon is installed; therefore, siphonage due to the discharge of the fitment is impossible, while the unsealing of the trap due to the discharge of an upper fitment is not possible, owing to the enlarged size of the main waste pipe (Fig. 2). The writer has carried out abnormal tests on a 3-in. cast-iron waste stack with a deep sink connected to it on each of five floors, in the manner previously described. The cubic content of the lowest sink trap was measured and the four sinks on the upper floors were discharged simultaneously; this resulted in a loss of only 5 cc. of water, which may be considered as negligible. Incidentally, further tests did not result in any additional loss. With repeated discharges from single sinks no loss was experienced. (*See further under* Anti-Siphon Pipe *and* Trap.)

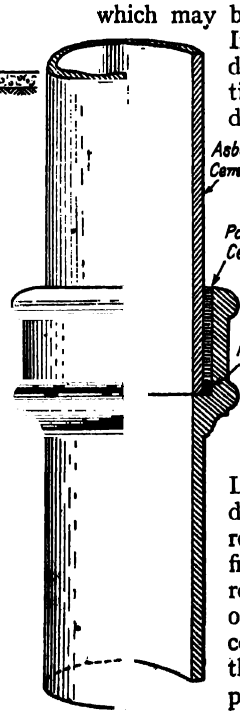


Fig. 3. Asbestos-cement soil pipe: sizes available, 3½-in. and 4-in. internal diameter; standard thickness, ⅜ in.; pipes and fittings supplied coated with mineral bitumen; joints easily made as shown. See also Fig. 1, p. 72.

Asbestos-Cement Soil Pipes. It is permissible to install cast-iron, wrought-iron, copper or lead for soil or waste pipes, either outside or inside the building in the London area; while in some districts the regulations still require lead for soil pipes if fixed within the building. Of recent years a new pipe of asbestos and Portland cement has been placed on the market for use as soil pipes. It has been used in some districts on housing schemes and is cheaper than iron, the joints being

made with Portland cement; as to its suitability, time will be the deciding factor, and it will be seen whether it will be generally adopted (*see* Fig. 3, also Fig. 1, p. 72, *under* Asbestos-Cement).

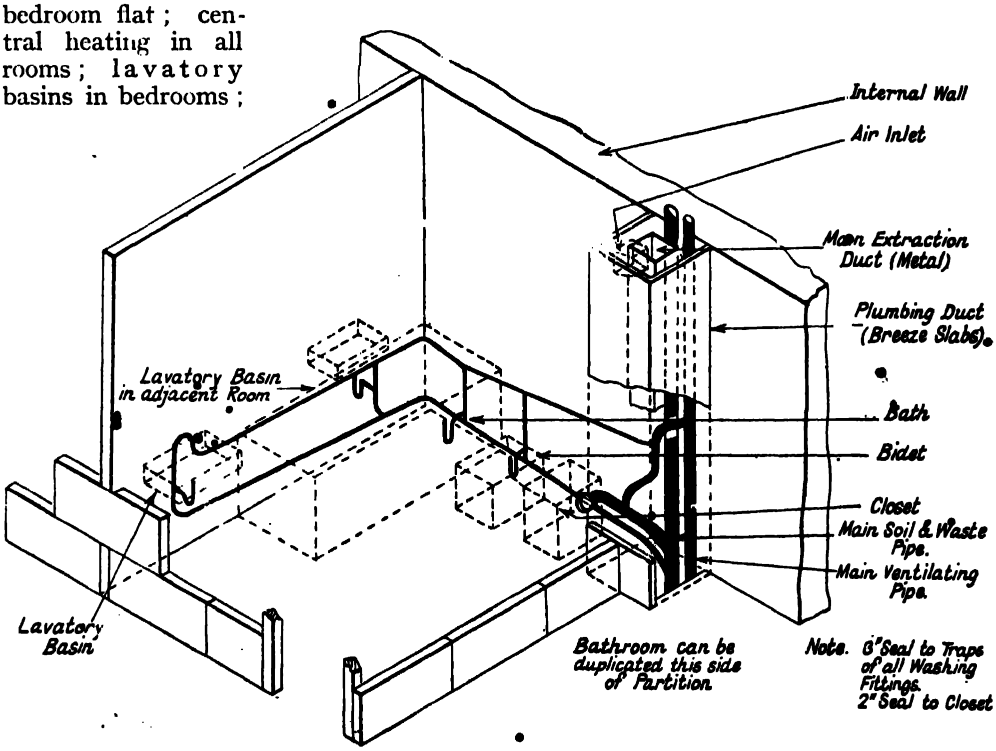
Some working-class flats are constructed on the " one pipe " system, which will be dealt with when describing high-class flats.

B. HIGH-CLASS FLATS

Since the Great War a vast number of residential flats have been constructed, not only in the London area but in the provinces and seaside towns. The fashion of having a town house appears, to a very large extent, to have been superseded by the vogue for a town flat. This has been brought about, particularly in the West End of London, by the fact that commercial interests have acquired the large town houses, while enterprising speculators are still constructing flats for occupation of those dis-housed; the servant question also plays a part in deciding in favour of a flat, which, of course, is more economical.

Amenities. The amenities of a modern flat have been greatly increased during the last few years. The provision includes several bathrooms to a three- or four-bedroom flat; central heating in all rooms; lavatory basins in bedrooms; refrigerators, electric fires; wiring for radio and television reception; gymnasium, bathing pool, squash courts; restaurant, hairdressing saloon; social club; pets' hospital; porterage, etc. In one large block of flats within the writer's knowledge, a bomb- and gas-proof shelter has been installed to accommodate 250 persons, the equipment including reconditioned air, lavatory accommodation in the form of chemical closets, lavatory basins, and fresh water storage.

Vertical Duct for Pipes. The trend of modern architecture, from a plumbing aspect, is to show no pipes either inside or outside the building; therefore a plumbing space has to be provided for their reception in the form of a vertical duct, constructed of breeze slabs on three sides, and built on to a partition wall or an external wall (Fig. 4). Usually the sanitary fitments are conveniently grouped so as to facilitate the fixing of waste, ventilating and service pipes to and from the fitments. The fitments to a bathroom generally consist of a water closet, bath, lavatory basin, and bidet (*which see*); the last-named fitment is now finding favour in high-class flats.



FLATS. Fig. 4. Vertical duct to take pipes, built against internal wall; layout of fitments planned to facilitate runs and fixing of waste, ventilation, and service pipes in relation to duct.

'One-Pipe' System. As in the case of the flats previously described, bathrooms and kitchens are planned above each other on succeeding floors, which renders the "one-pipe" system of plumbing more adaptable for installing. This system is now common practice in the London area, and is provided for in the 1934 Revised By-laws of the London County Council. The section dealing with sewage drains and their ventilation refers to

"the waste pipe or ventilating pipe of any waste water fitment where such pipe is connected directly to such drain . . . shall be deemed to provide the necessary means of ventilation."

Waste water fitments, when fixed in direct contact with drain air and not connected to a gully trap, must comply with the following section:

"If such waste pipe or ventilating pipe is connected directly with any sewage drain or sewage drain ventilating pipe, and any trap connected therewith shall be in conformity with the following requirements."

[The following is an abbreviated form of the By-law, indicating the salient points.] "Such waste pipe and ventilating pipe shall be constructed . . . in the manner prescribed for soil pipes . . . the internal diameter . . . shall be not less than one and a quarter inches; . . . shall be trapped immediately beneath such fitment by a suitable and efficient tubular trap; . . . such trap shall be formed and fixed so as to be capable of maintaining a water seal of three inches where such inlet has an internal diameter of less than three inches."

It will be seen that a waste pipe or a waste pipe stack can (if the conditions permit) be connected direct to the drain, and need not, as is sometimes supposed, be always connected to a soil pipe. (*See* the heading "One-Pipe" System for full details).

Planning of Fitments. The arrangement of the fitments in a well-planned bathroom will provide a loop or circuit, the lower portion being used for the waste and the upper part for ventilation purposes, and vertical pipes can be installed between the waste and the ventilation pipes for the purpose of connecting the traps from the fitments, as shown in Fig. 4.

The writer has carried out a number of severe tests on systems installed on these lines, with excellent results.

Shower Bath. Shower baths are often provided for by some architects and are very economical in their use of water, requiring only about one-fourth the amount necessary for the ordinary panel bath. With the porcelain-enamelled iron shower-bath tray the outlet is usually in the centre; this position makes it impossible to comply with the By-laws regarding the ventilation pipe of the trap (being taken not more than 12 in. from the crown of the trap), seeing that the trap is very close to the underside of the tray. It is therefore usual to connect the pipe into the waste pipe immediately it passes the tray; if there is a false ceiling beneath, allowing for a good fall to the waste pipe, the ventilation can be fixed within the 12 ins., as specified in the By-laws.

Closet Apartment Ventilation. Water-closets fixed in an apartment which has an external wall must have a window at least 2 sq. ft. in area, and permanent ventilation, and abut upon an open area or space at least 100 sq. ft. in area, with a minimum width of 3 ft. if enclosed on not more than two sides, and 7 ft. if entirely enclosed. Basement closets may have a restricted area of 40 sq. ft. with a minimum width of 5 ft.; and if the area is used exclusively for light and ventilation of the closet apartment, then a further restricted area of 25 sq. ft. is permissible. It was not until 1930 that basement closets were legalized in the London area, and concession from the local authorities was necessary prior to that date.

Mechanical Closet Ventilation. A large number of modern flats are planned with a centre corridor through the length of the building, with flats on either side. The entrance door to the individual flat opens on to a small hall with the habitable rooms facing; on one side of the hall is a bathroom containing a closet, and on the other a kitchen; both the two latter apartments are constructed internally (*i.e.* they have no external wall).

It is necessary, therefore, to provide mechanical ventilation for the closet apartment by means of a main duct, with branches from each closet apartment joining the main at ceiling level. The air is drawn from the apartment by means of an electrically driven fan which exhausts the air at the rate of 750 cu. ft. per hour; or, if the apartment contains the closet only, then the rate must be three complete changes of air per hour. Fresh air inlets are required to be provided. This last provision appears to be not only superfluous but illogical, as it is most undesirable to have a current of cold air passing

over one's body when leaving a warm bath in the winter season.

From many tests the writer has carried out on these ventilating systems there is practically no difference in the rate of extract whether a fresh air inlet is provided or not; the same comment is applicable when the door of the apartment is open or shut and no fresh air inlet is installed.

The London County Council By-Laws on inside closets appear very clear and are worth quoting:

"If so situated that none of its sides is an external wall and an open area is not provided," [shall] "have suitable means of artificial lighting and a suitable system of mechanical ventilation complying with the following requirements: (i) The system of ventilation shall be separate and distinct from any system of ventilation installed for any other purpose" [which means that the kitchen ventilation system cannot be joined to the closet ventilation system in the scheme under discussion]. "(ii) A sufficient number of suitably placed fresh air inlets shall be provided." [This has been taken to mean that a duct shall provide external air to the apartment.] "(iii) The fan and motor or other mechanical means shall be in duplicate, and capable of extracting air from the water-closet at a minimum rate of 750 cu. ft. per hour per soil pan or basin. The aerial content of the water-closet shall be changed at least three times per hour." [The fan and motor are required to be in duplicate in order that the second set shall act as a standby in case the first set should fail.]

Testing Extraction. The method adopted for testing the rate of extraction of air from the apartment is to use an anemometer. This is a small metal rotary fan with metal blades, very finely adjusted, which actuates index dials and records the rate that air is being drawn from the apartment through the metal grating attached to the branch duct.

It is usual to allow the test to be applied for one minute, thus recording extract of air in lineal feet per minute of the effective area of the grating, which must be calculated to its proportion of a square foot. This amount, when multiplied by the lineal feet recorded, will indicate the amount in cu. ft. extracted per minute; this, when multiplied by 60, will give the amount in cu. ft. extracted per hour. Another method, which the writer has found more exacting, is to make a flat, square pyramid of metal the exact size of the grating and form an opening in the apex just large enough to insert the circular anemometer. This has the effect of increasing the speed, owing to the smaller opening. All air extracted must, therefore, pass through the anemometer and be recorded. If the closet apartment is a small one, such as frequently occurs—say, 5 ft. × 3 ft. × 8 ft. high—the cubic content of the apartment will be 120 cu. ft., and to apply that portion of the By-Law requiring 750 cu. ft. per hour would result in at least six changes of air in that period, and cause the apartment to be very cold during the winter season. Therefore the three changes per hour, as specified, should be applied.

Closet Approached from Bedroom. Another provision of the L.C.C. By-Laws, which adds greatly to the amenities of the flat, provides that "a water-closet used exclusively with a bedroom or dressing room may be entered directly from such room." This provision is very acceptable in high-class flats where a bathroom adjoins the bedroom. Prior to 1930, when the By-Law was passed, a closet was a prohibited fitment in the bathroom if entered directly from a bedroom, and was required to be placed within a separate apartment either constructed within the bathroom or on the landing adjoining; now it can form one of the bathroom fitments, if used only by the occupants of the bedroom.

FLOW PIPE. The "positive" pipe in the primary circulation ascending from a boiler conveying hot water to the upper portion of a circulating cylinder. In a secondary circulation also the flow pipe is the positive pipe—*i.e.* that portion of pipe branching from the top of a hot-water cylinder to feed the various hot taps on the domestic supply. After the last hot branch it becomes a "return" pipe to the cylinder.

Similarly, the flow pipe in a heating system conveys the heated water from the highest point of a boiler, ascending throughout a building and descending from its highest point as a "return" to the bottom of the boiler. In the single-pipe system of a low-pressure heating apparatus the flow pipe ascends from the top of boiler to supply radiators. The small branches taken from the *top* (where horizontal) of this flow pipe are "flow branches," and the radiator returns are branched in at the *side* of the flow pipe.

The flow pipe from a town's storage reservoir is the pipe taken from near the reservoir bottom to supply the town's water.

FLUES: FOR GAS-FIRED BOILERS, FIRES & OTHER GAS-BURNING APPLIANCES

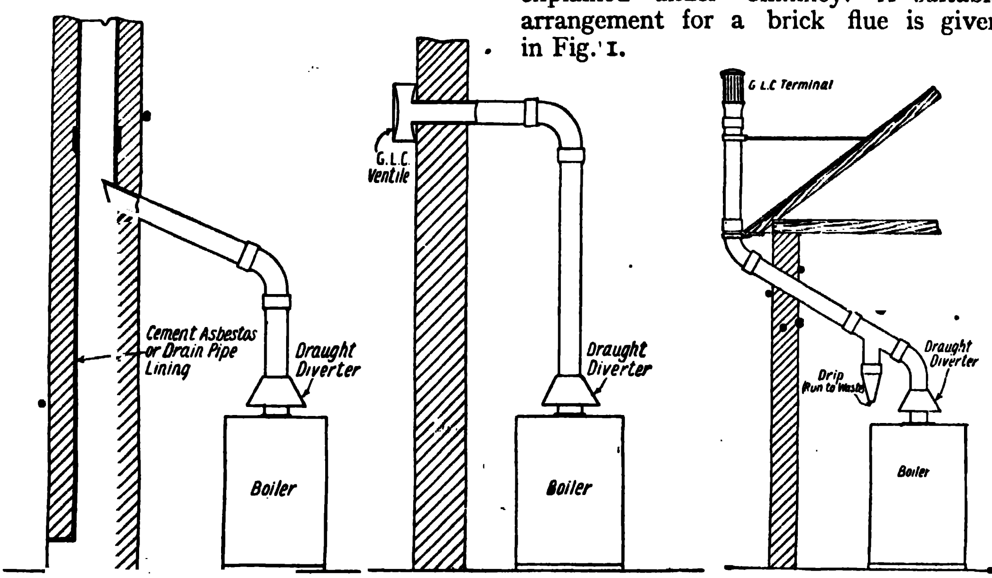
By L. C. C. Rayner, A.I.E.C.

This article is devoted to flues and flue accessories needed for gas-burning appliances. (For flues to boilers and other appliances using solid or liquid fuel, see Chimney.) In the present contribution Mr. Rayner discusses the essential requirements for a proper flue system. See Asbestos-Cement; Gas Fitting.

It is good practice to provide a flue for every gas-burning appliance ; those burning up to 10 cu. ft. of gas per hour per 1000 cu. ft. of room volume, are often fixed without a flue, provided the room has adequate ventilation. Beyond this consumption a proper flue should certainly be used.

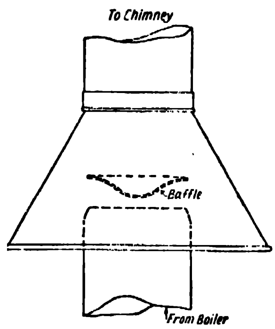
The requisites of a proper flue are: adequate area to carry off the products of combustion ; termination in a suitable position so that under no wind conditions can a down-draught be formed ; the absolute prevention of a blow-back extinguishing the flame ; means for removing water of condensation that may form ; resistance to corrosion. In contradistinction to the flue for a solid fuel boiler, draught plays very little, if any, part in the flue for a gas appliance, since there is no fuel bed through which air must be "pulled."

Condensation Troubles. The products of combustion of town's gas consist very largely of water vapour. So long as the flue temperature remains above the dew point (about 120° F. to 130° F. usually), the water vapour will not condense. Modern gas boilers are so efficient that the flue gases leave them at quite a low temperature, and almost always cool below the dew point before leaving the chimney. The water of condensation thus formed will seep through the brickwork of an ordinary chimney, staining the plaster. If such a chimney is to be used it must be lined with glazed tiles, glazed sewer pipe, or asbestos-cement pipe. Where it is impossible to do this (as in the case of an existing chimney), the chimney should not be used and an independent flue pipe should be run. Where a brick chimney is employed the pipe lining should be fitted with sockets uppermost, the joints being made with lead wool thinly covered with cement. The area of the chimney should be not less than that of the boiler flue outlet. To prevent down-draught the chimney should terminate above surrounding objects, as explained under Chimney. A suitable arrangement for a brick flue is given in Fig. 1.



FLUES : Gas-burning Appliances. Fig. 1 (left). Boiler flue discharging into brick chimney lined with asbestos-cement or glazed drain pipe and having socket turned upward. Fig. 2. Independent flue where no chimney is available, with G.L.C. "Ventile" on outside wall (well clear of windows). Fig. 3. Independent flue carried above eaves of low building, with G.L.C. terminal. All three require baffle (see also Fig. 4) above boiler.

Independent Flue. When an independent flue is to be run, asbestos-cement pipes are the only suitable material in the case of boilers. Metals, unless protected, must not be employed, because the slightly acid fumes quickly corrode, particularly with condensation. The flue should be finished with a terminal which will prevent down-draught, such as the G.L.C. "Ventile" for wall fitting and the G.L.C. terminal for vertical pipes. These are shown in Figs. 2 and 3 respectively. If in Fig. 2 the horizontal pipe has an appreciable length, the vertical part must be at least twice as long as the horizontal. The terminal must be kept well clear of windows, to avoid fumes entering the rooms. In the case shown by Fig. 3 the same precautions should be taken against down-draught as with an ordinary chimney.



FLUES: Gas-burning Appliances. Fig. 4. Baffle or draught diverter as indicated in use in Figs. 1, 2, and 3.

Down-Draught Prevention. Precautions should always be taken to ensure that any down-draught in the flue cannot extinguish the gas flame. This is of particular importance with boilers which use a self-pilot. In these no separate pilot light is used, but when no heat is required the main gas jets are closed down until they are only about ¼ in. high. In this state they are particularly easily extinguished and, moreover, the fact may easily go unobserved. A break must therefore be made in the connexion between boiler and chimney. Often the boiler is fitted with a baffle (*which see*) or draught diverter, one example of which is shown in Fig. 4. If this is not the case, one must be fitted. Occasionally a flue tee is used instead. It is fixed in a vertical position, the top going to the chimney, the bottom being open to atmosphere, and the branch going to the boiler. *See* Gas Fitting.

Gas Boilers. It is usually found, as mentioned above, that a gas boiler flue produces a lot of water of condensation. If a brick chimney is used, a grating or opening into the chimney below the boiler connexions will often prevent any trouble. Failing this it is sometimes possible, by adjusting the draught diverter, to prevent the condensation of water. If sufficient air be allowed to flow up the chimney there is insufficient moisture to saturate it, and the diverter is adjusted until the right quantity of air enters the chimney. However, on cold days it may be found that the flue gases are cooled so much that condensation still occurs. To avoid trouble altogether a drip should be used (Fig. 3). This consists of a tee with the outlet looking down, inserted in the flue pipe. The outlet is fitted with a reducer from which a drain pipe is run to a gully or sink. This pipe should be not less than ½ in. and preferably ¾ in. in diameter.

Gas appliances other than boilers need equal care in arranging for the disposal of the flue gases. It must be remembered that incomplete combustion occasionally takes place, resulting in the production of carbon monoxide. This is poisonous and quickly fatal if inhaled. Gas fires should always have a flue connexion, and if an existing chimney is used it should be tested to check that it is not subject to down-draught. This may be done with a lighted piece of paper. If down-draught is found the chimney must be extended or an individual asbestos-cement flue run.

Small gas boilers should be treated in a similar manner to larger boilers, as already described. Usually condensation trouble is not experienced because the flue gas exit-temperature is higher.

Geysers. A geyser must have a flue. No provision need be made in the flue for condensation, since the geyser itself will have a condensation drip from its tray. This should be taken into the bath waste above the trap, never into the bath. If taken into the latter the condensation will quickly discolour and eventually destroy the bath enamel. In the past the flue outlet from a geyser has often been allowed to discharge into the roof space above the bathroom. It is better to avoid this, taking the flue into the outer air. It should be fitted with a proper terminal and an efficient baffle.

The products of combustion from gas cookers are usually allowed to discharge straight into the room, so there is no possibility of back-draught. If a flue is fitted it should be treated similarly to those of other gas-burning appliances.

Where more than one gas-heated boiler or other fitting is adjacent to a suitable brick flue they may all be connected to it. In no circumstances, however, should boilers burning solid or liquid fuel be connected to the same flue as a gas-burning fitting, owing to the greater possibilities of corrosion and, perhaps, explosion. It must be remembered that gas requires air to burn it, and without an adequate air inlet to the boiler room the gas flames may tend to leave the jets and may go out. If necessary inlet gratings should be provided.

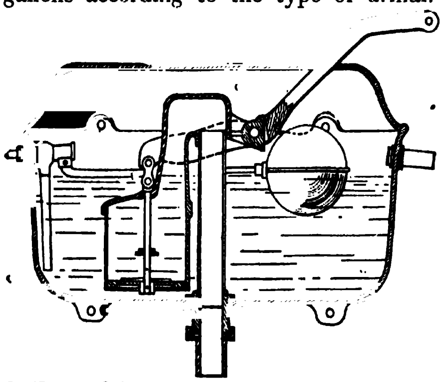
FLUES: for Solid-fuel Boilers, etc. These are discussed under the heading Chimney (*which see*). Flues for gas-fired boilers are dealt with under their own heading, in the article immediately preceding, beginning in page 426.

FLUSHING CISTERNS AND TANKS

By Percy Manser, M.R.San.I., R.P.

Flushing cisterns for Water Closets and Urinals are discussed in the first part of this article, the various types being described and their working explained. A section deals with faults and their remedy, and another gives extracts from the M.W.B. by-laws. Automatic Flushing Tanks for drainage systems are the subject of the final section. See Flushing Valve; Water Waste Preventer.

Flushing cisterns or tanks are of two kinds: hand-operated and automatic, and both are used for flushing sanitary fittings. The first named are waste preventing cisterns used mostly in association with water closets, and have a capacity of two gallons. In certain cases the permitted capacity is three gallons. They are sometimes used for urinal flushing, and the capacity may be one or two gallons according to the type of urinal.



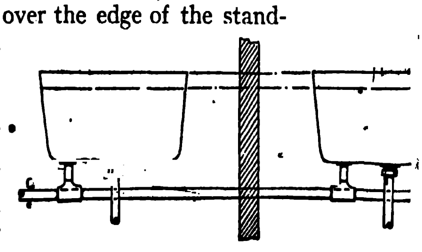
FLUSHING CISTERNS AND TANKS. Fig. 1. Valveless siphon cistern: enamelled iron shell, lead siphon, lugs for screwing into wall. Siphonage started by pull on lever attached to disk in cylinder.
Shanks & Co., Ltd.

Capacity as mentioned here is the amount of the actual flush. Automatic tanks are used for various purposes, *e.g.* flushing grease traps, drains, urinals, trough closets, etc.; they vary in capacity from one to thirty gallons for ordinary use.

A. WATER WASTE PREVENTERS

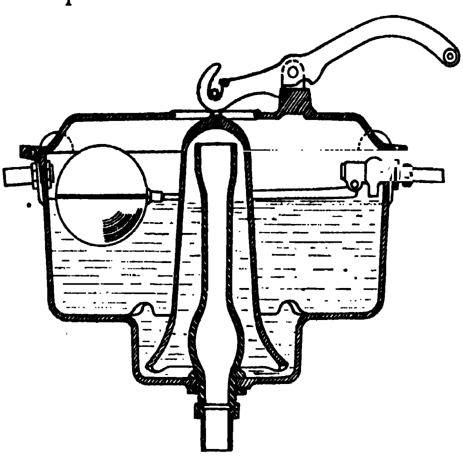
Waste preventers are of the siphonic type and valveless, *i.e.* the contents must be discharged by siphonic action without the use of a valve which will permit water to pass into the flush pipe other than by way of the siphon. There are numerous types, made in cast-iron either painted, galvanized or porcelain enamelled; porcelain enamelled fireclay; and wood with sheet-lead or copper linings. The manner in which siphonic action is brought about varies with different makes, but in the main it consists of simple mechanism, actuated by a chain pull and lever or by a lever alone, which lifts or forces water over a siphon bend to displace the air sufficiently to set up siphonage. In some makes this is done by the downward pull of the chain lifting a piston rod attached to a plate or disk within a cylinder; the disk throws water over the siphon bend; and siphonage of the contents of the cistern follows. Fig. 1 shows a waste preventer of this type.

One of the simplest forms of cistern is the bell siphon pattern, which operates on the "pull-and-let-go" principle (Fig. 2). The chain is pulled and on being released the bell is allowed to drop back into the well of the cistern; this causes water to pass over the edge of the standpipe and set up siphonage.



There are numerous excellent types of water waste preventer (*which see*),

the chief of which are discussed later in this work; certain important points should be emphasized here. Cisterns should be



FLUSHING CISTERNS AND TANKS. Fig. 2. Bell valveless siphon cistern: enamelled iron shell, reversible cover and lever. After pulling, releasing lever starts siphonage.
Shanks & Co., Ltd.

as silent as possible in action; without too many working parts; should fill within two minutes after the appliance is flushed.

It should be pointed out with respect to the last item that many of the cheaper makes of cistern are provided with high-pressure ball valves, and these have been fixed regardless of the head or pressure of water available, with the result that complaints soon arise about the time taken to obtain a second flush. On inspection it is often found that such delay is due to a low head of water and a high pressure valve. It is important to fit the cisterns with valves to suit the existing water pressure if a satisfactory and sanitary job is to result. In addition to the items mentioned here, the plumber should be acquainted with the by-laws in force in the district.

Low Level Cisterns. The flushing cisterns used with low-down w.c. suites are similar in all respects to those for high level cisterns. There are, however, certain variations, in that some types are fitted with submerged supply valves connected through the bottom of the cistern. The main difference is that they are operated by a small hand lever or push-in knob, and the flush pipe (which is often a unit supplied with the cistern) is, as a rule, of a larger bore than the longer flush pipe fitted to a high level cistern.

Ranges of Closets. Ranges of water closets are often fitted with waste preventers without the usual overflow pipe and ball valve. The supply is from a master cistern fixed at the end of the range (Fig. 3), and one ball valve and one overflow pipe only are necessary. A feed pipe from the master cistern is carried along beneath the preventers, with a branch pipe connected to the bottom of each. Another type is the continuous trough for ranges of closets, which is a long trough of galvanized steel or glazed fireclay fixed along the top of the apartments (Fig. 4). The trough is fitted with siphon, lever and chain pull for each w.c., and only the permitted flush is allowed to pass each time the apparatus is used. One

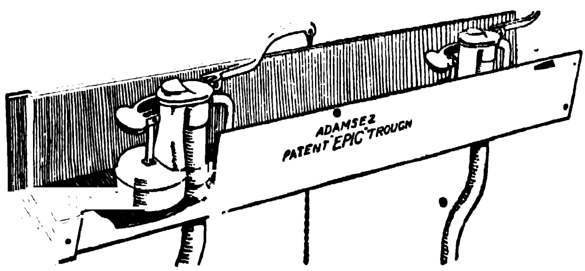


Fig. 4. Continuous overhead trough for range of water closets, with siphon, lever and chain pull for each closet; one overflow pipe and one or two supply valves.
Adamsez, Ltd.

overflow pipe only is required, and one or two supply valves, according to the number of water-closets in the range.

Operation of Flushing Cisterns. Based upon the siphon principle, in which the flush pipe is the long leg and the

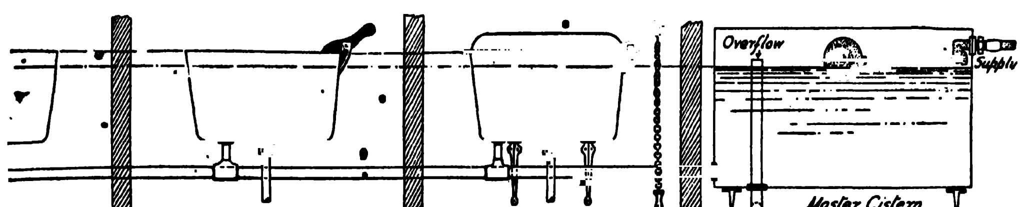
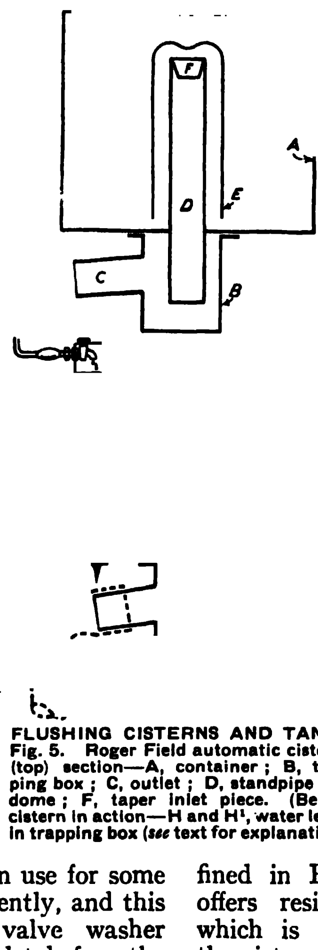


Fig. 3. Gravity-fed flushing cisterns for range of closets; one master cistern containing ball valve and overflow; feed pipe carried below individual cisterns.
Shanks & Co., Ltd.

siphon in the cistern is the short leg. In the case of hand-operated cisterns the air in siphon and the flush pipe is normally at the atmospheric pressure of 14·7 lb. per sq. in. To bring about a reduction of this pressure (usually referred to as a partial vacuum), water is induced by various ingenious methods to pass suddenly into the flush pipe via the siphon bend or the standpipe. This sudden reduction of pressure is followed by the immediate discharge of the contents of the cistern, caused by the pressure of the atmosphere upon the surface forcing the water downwards to replace the partial vacuum. As the water level approaches the bottom of the cistern the siphonage is "broken" by the admission of air, which is arranged for in various ways according to the make of cistern.

In some makes siphonage cannot be induced unless the cistern fills to a certain level, and this has often been the cause of complaint. The trouble is, of course, due to the ball valve not functioning correctly, and closing before the cistern has filled. Most cisterns are plainly marked with a line and the words "WATER LINE" cast in raised letters with the cistern shell; the ball valve should close when the water reaches this line. Cisterns which have been in use for some time often fail to fill sufficiently, and this is usually due to the valve washer swelling and closing the inlet before the water has reached the correct level.



FLUSHING CISTERNS AND TANKS. Fig. 5. Roger Field automatic cistern: (top) section—A, container; B, trapping box; C, outlet; D, standpipe; E, dome; F, taper inlet piece. (Below) cistern in action—H and H¹, water levels in trapping box (*see* text for explanation).

B. AUTOMATIC CISTERNS

Automatic cisterns as the name implies, are self-acting, and siphonage is brought about by either a drip supply or a reverse-action ball valve according to the type of siphon provided. The first are those in which the cistern is filled completely by a continuous drip, regulated by means of a petcock, or by some special fitting such as the disk supply union of the Metropolitan Water Board. This consists of a metal disk contained in a union fitting; a tiny hole is bored in the disk, which permits a measured quantity of water to pass in a given time according to the pressure and the intervals between which the cistern is required to flush.

The reverse-action valve is a fitting which permits a dribble of water to pass until the cistern is nearly full, when the ball float rises, opens the valve, allows water suddenly to enter, fills the cistern and sends a volume of water into the siphon, and sets up siphonic action.

Different forms of siphons are used in each case. A well-known automatic appliance is that which was invented by the late Mr. Roger Field, C.E. This is shown in Fig. 5, and it will be seen that it consists of container A; trapping box B, with outlet C; standpipe D, and dome E, which together form an annular siphon. The standpipe terminates below the level of the outlet pipe, forming a trap. At the top of the standpipe is a small taper inlet piece F. The object of this is to conduct the water clear of the sides as it passes over the edge of the pipe. The trapping box B is first charged. As the cistern fills, the air confined in E and D is compressed, and offers resistance to the rising water, which is therefore lower than that in the cistern and rises more slowly. When water reaches the top of the standpipe it passes over the lip drip by drip, until the water level H is forced down to H^1, and air begins to escape; the pressure is thus suddenly reduced and water rises quickly within the dome, passes in volume into pipe D, displaces the air and sets up siphonage. As the water reaches the bottom of E, air is admitted and the cistern begins to refill. The level to which the water rises in the cistern is shown in the diagram, and is equal in

height above the top of pipe D to the depth of submersion of D in the trapping box. This is necessary to obtain sufficient compression of the confined air in order to force the water level down from H to H^1.

Supports for Cisterns. The supports for flushing cisterns are usually brackets of cast-iron of the cantilever or screw-on type and may be painted, galvanized, or porcelain enamelled. The cantilever pattern has projecting lugs for building into the wall, and these should be firmly set in Portland cement mortar. The screw-on pattern may be fixed (*a*) by Rawlplugs; (*b*) to a backboard which in turn is firmly fixed to plugs or blocks; (*c*) by hardwood plugs or blocks firmly embedded in the wall (Fig. 6). Ordinary softwood plugs are seldom successful, as they shrink and become loose. Backboards are generally used when the wall face is of plaster or plain brickwork. For glazed or tiled surfaces the brackets should be fixed direct to the wall by method (*a*) or (*c*). Where ranges of w.c.'s occur and the cisterns are fixed to the side wall they are sometimes fixed back to back and bolts passed through to secure the brackets, as in Fig. 6 (*d*).

C. WATER BOARD REGULATIONS

Extracts from the by-laws concerning flushing cisterns and made under Section 16 of the Metropolitan Water Board Act, 1932, are given here:

By-Law 56. Cast-iron flushing cisterns shall be not less than three-sixteenths of an inch thick with a bead round the top and shall be efficiently protected against corrosion.

By-Law 58. The siphon, or dome and discharge pipe, as the case may be, of every flushing cistern shall either be of corrosion resisting materials or be efficiently protected against corrosion.

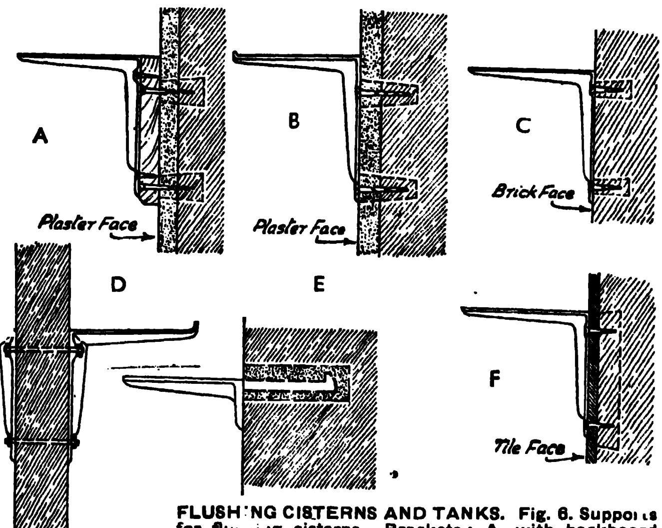
By-Law 59. The ball tap of every flushing cistern shall be of such design as to allow the cistern to fill within a period not exceeding two minutes after the cistern is operated, and shall close when the water reaches the water line.

By-Law 60. In every water closet flushing cistern of a capacity not exceeding two gallons the outlet nipple, the tail pipe and the flush pipe shall each be not less than one and a quarter inches in internal diameter.

By-Law 63. A flushing cistern provided in connexion with a water closet or urinal shall be so constructed and maintained that water cannot flow down the flushing pipe except whilst a flush is being properly delivered, and so that it shall not discharge at one flush more than its permitted capacity.

By-Law 68. A person shall not fix, fit or use upon any premises any self-acting or automatic flushing apparatus through which water of the Board is intended to pass unless the water passing through such apparatus shall be supplied by measure.

It has been mentioned that flushing cisterns to w.c.'s should be of the valveless type, but this requirement does not apply to flushing cisterns fitted in certain classes of building in which the water is supplied by measure, provided that practicable steps are taken in the construction of such cisterns to prevent waste, misuse or contamination of water. A similar provision is made in respect of the permitted flush of 2 gallons. In certain classes of building a flush of 3 gallons is permitted if the water is supplied by measure, and steps are taken in the construction of such apparatus to prevent waste, undue consumption, misuse or contamination of water.

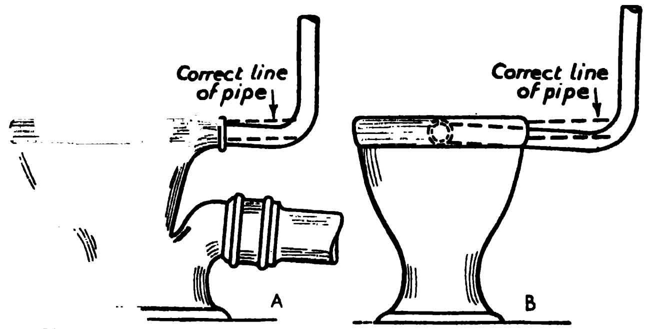


FLUSHING CISTERNS AND TANKS. Fig. 6. Supports for flushing cisterns. Brackets: A, with backboard fixed to [illegible]dged and expanded wood plugs; B, fixed to ordinary taper wood plugs (wrong method); C, screwed direct to "dovetail" wood plugs in brickwork; D, back to back and bolted together through partitions in w.c. range; E, cantilever built-in bracket; F, bracket fixed to wood grounds behind tiled face.

D. FAULTS IN FLUSHING CISTERNS

Failures of flushing cisterns may be due to various causes, and in many cases a knowledge of simple physics will help to determine what is wrong. Improper filling with certain types has been mentioned.

Another cause of failure is a faulty flush pipe; where the pipe enters the basin nozzle a pocket retaining water (as shown in Fig. 7) has been sufficient to prevent



FLUSHING CISTERNS AND TANKS. Fig. 7. Pockets which prevent siphonage, formed by badly fitted flush pipe: A, pipe fixed centrally on back wall; B, pipe passing down corner of apartment.

siphonage taking place. Failures have been caused by w.c. basins fitted with an "after flush" chamber. This chamber is drained into the basin by a small weep hole, as shown in Fig. 8. Stoppage of this weep hole has been sufficient to prevent siphonage, owing to the water in the chamber partially blocking the air passage through the inlet nozzle. Three instances of bell siphon cisterns which continued siphoning in spasmodic jerks after being flushed appeared to be due to the base of the bell being flooded by fast incoming water before the siphonage was "broken," and the following cures were effected.

Case A. Bell and standpipe, which were thickly coated with rust, were cleaned and coated with bitumastic paint as a protection.

Case B. A small hole was drilled in the bell near the bottom to admit air.

Case C. The incoming supply was throttled down by inserting a perforated disk in the tail piece of the ball valve after disconnecting the supply union.

Failures of automatic cisterns when the fitting and the water supply are in good order are generally due to a partial stoppage of the flush pipe. Failure of a cistern supplying a urinal was due to choked holes in the galvanized iron sparge pipe or sprinkler. A cistern used for flushing a grease gully failed because the inlet connexion of flush pipe to the gully became partially choked with grease. It was discovered that large quantities of greasy water were being discharged into the gully, and the cistern was flushing only at long intervals: hence the accumulation of grease at the inlet. More frequent flushes overcame this trouble.

E. FLUSHING TANKS FOR DRAINAGE SYSTEMS

Automatic flushing tanks are used in connexion with grease traps and grease gullies (both of which are described under Grease Trap). These traps are designed to hold a fairly large quantity of water to cool the grease and prevent it passing into the drain in a semi-liquid state where it would solidify and in time cause a stoppage; this is a too frequent occurrence where grease in quantity is allowed to enter the drain. The flush tanks are of the automatic type and vary in capacity from 10 to 20 gallons according to requirements: they are usually fed by a drip supply regulated to permit flushing at intervals which are determined by the amount of greasy discharges the trap is to deal with per 24 hours. The sudden discharge of a large volume of water prevents undue accumulation of grease, scours the trap and conveys the contents through the drain and intercepting trap into the sewer.

Flush-out grease traps are necessary where large quantities of greasy water are discharged into the drains (as in hotels, restaurants and similar buildings), but where the water supply is limited a different type of trap which does not require flushing out is used, the grease being removed periodically by hand. The automatic tanks used for grease trap flushing may be of the Roger Field type, shown in Fig. 5, although other makes which work by drip supply are obtainable. The tank should be fixed well above the grease trap, to permit of a good head and thus produce a scouring effect and complete removal of the grease.

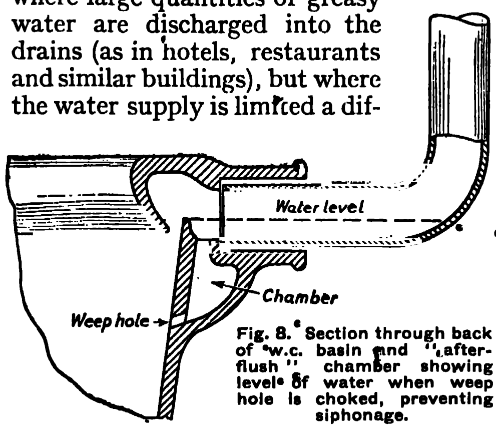


Fig. 8. Section through back of w.c. basin and "after-flush" chamber showing level of water when weep hole is choked, preventing siphonage.

Drain-flushing Tanks. It is often necessary to provide means for flushing drains in order to cleanse the interior and remove any solid or liquid matter which the discharges from usual fitments fails effectually to carry away.

This is especially applicable to lengthy drains which do not receive waste water in sufficient volume to enable them to be self-cleansing; or to drains which must of necessity be laid to a low gradient. The usual fall for a 4-in. drain is 1 in 40 (*i.e.* 3 in. in 10 ft.),

Diameter of drain in inches	Length in feet	Capacity of tank in gallons
4 in.	40 to 60	20 to 30
4 in.	75 to 120	50 to 60
5 in.	40 to 60	30 to 40
5 in.	75 to 120	60 to 75
6 in.	40 to 60	50 to 60
6 in.	75 to 120	70 to 120

but they must often be laid at less gradient than this. It is a good plan if the discharge from a bath or baths enters the drain at the highest end, as this provides a good volume of water for cleansing. It is not

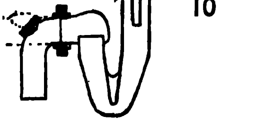
FLUSHING CISTERNS AND TANKS. Fig. 9. "Vedas" silent cistern: note dip pipe carried to bottom of cistern to avoid noise from incoming water.
John Bolding & Sons, Ltd.

always convenient to arrange this, however, and where periodic flushing is necessary, an automatic tank is provided at the head of the drain. The capacity of the tank will vary according to the size and length of the drain. In deciding the capacity, various factors must be considered, such as diameter, length, gradient and run of the drain. The table in col. 1 is a guide to the capacities of tanks for various diameters and lengths of drain.

Like those for grease traps, these tanks are of the drip supply pattern such as the Roger Field or Burns' Certus auto flush tank (Fig. 10). It is usually sufficient if the tank is regulated to discharge once or twice per 24 hours, but this must be governed by local conditions.

FLUSHING VALVE. A fitting which when operated permits a predetermined quantity of water to pass for the purpose of flushing a sanitary fitment. The amount of water used for flushing water closets (especially those of the valve type) was at one time much in excess of the quantity permitted at the present time. To meet the requirements of water supply authorities, valve closets having special supply valves were introduced and these were adjusted to suit the head of water so that only a given quantity (usually two gallons) could pass each time the fitting was used.

The old type valve closets were replaced by pedestal wash-down closets and water-waste preventers. Later flushing valves were introduced. These fittings are neat, occupy little space, are



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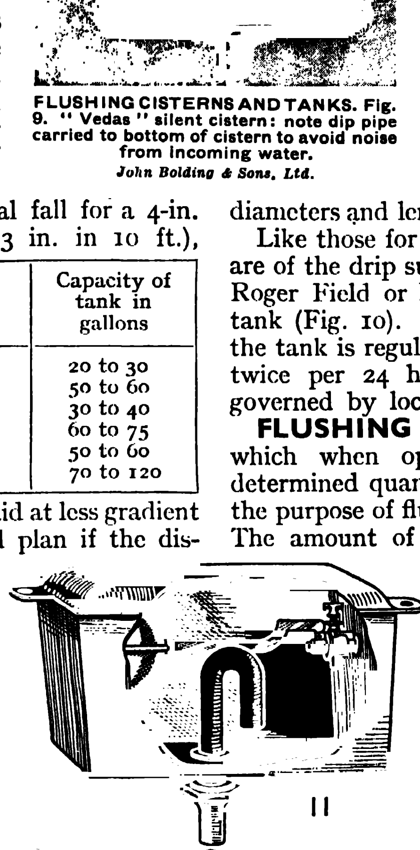

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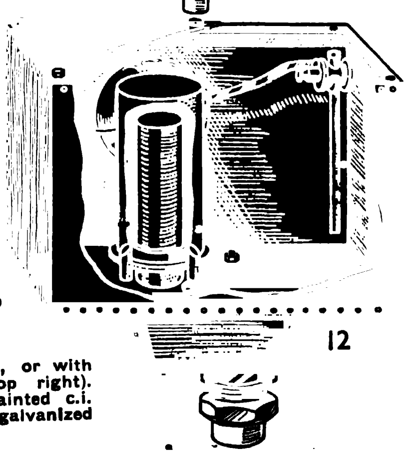

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Fig. 10 (above). "Certus" automatic flushing tank for drains, which will discharge with a slowest feed (Burn Bros., Ltd.): tank and castings galvanized; outlets can be fitted with flange and spigot pipe straight or bent, or with flange for lead pipe. Fig. 11 (top right). Automatic flushing cistern, painted c.i. Fig. 12. Automatic flush tank, galvanized iron, regulating valve.
Thos. Crapper & Co., Ltd.

FLUSHING VALVE. Fig. 1. "Ormonde" siphonic pedestal closet, glazed fireclay, adjustable lead trap; "Quantum" flush valve, 1¼ in., chromium plated, push-button operation.
Dent & Hellyer, Ltd.

fixed direct to a supply pipe, and can be adjusted to suit the head of water under which they are to be fixed, so that only a pre-determined quantity of water is allowed to pass each time the fitting is used. Certain objections have been raised to these valves, one of which is that they may become leaky and allow water to pass to waste without detection; and they have not been approved by all Authorities. Figs. 1 and 2 show the "Quantum" valve (which is provided with a leakage indicator) as fitted to a pedestal closet. Flushing valves must be fed from a cistern (except private supplies); each valve must be regulated to the particular head available, which will vary on different floors.

The Twilon W.C. "Flushometer" valve is shown in Fig. 3, and the "Hydrus" Flush valve in Fig. 4.—*Percy Manser, M.R.San.I.*

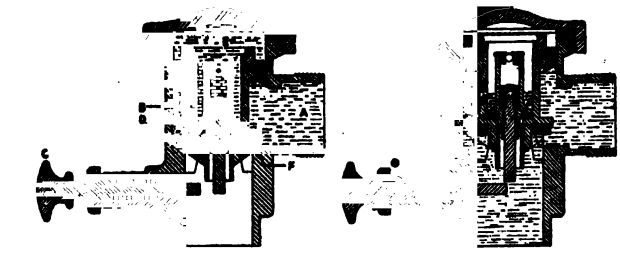


Fig. 2. "Quantum" valve operation. Inlet A is connected by full-way pipe to main supply or storage tank. Equal pressure is established on both sides of main valve by water leaking through small bleed hole B in body of main valve. Pressure of push knob C tilts stem of auxiliary valve D (which is free to move within main valve) and disturbs equilibrium by allowing water in top chamber E to escape quickly down past seating of auxiliary valve to outlet. Pressure on top of main valve being suddenly relieved, this valve is allowed to rise off main seating F and water passes through free passage made between inlet and outlet. Meanwhile, water passes slowly through bleed hole again, and as soon as top chamber is full, valve closes completely.

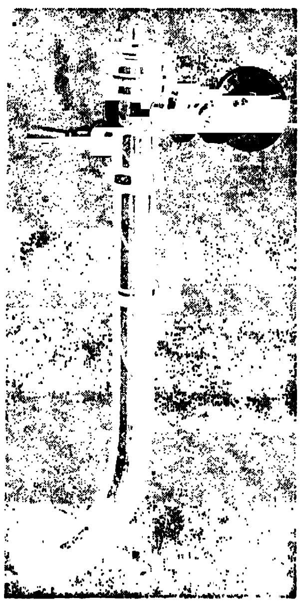
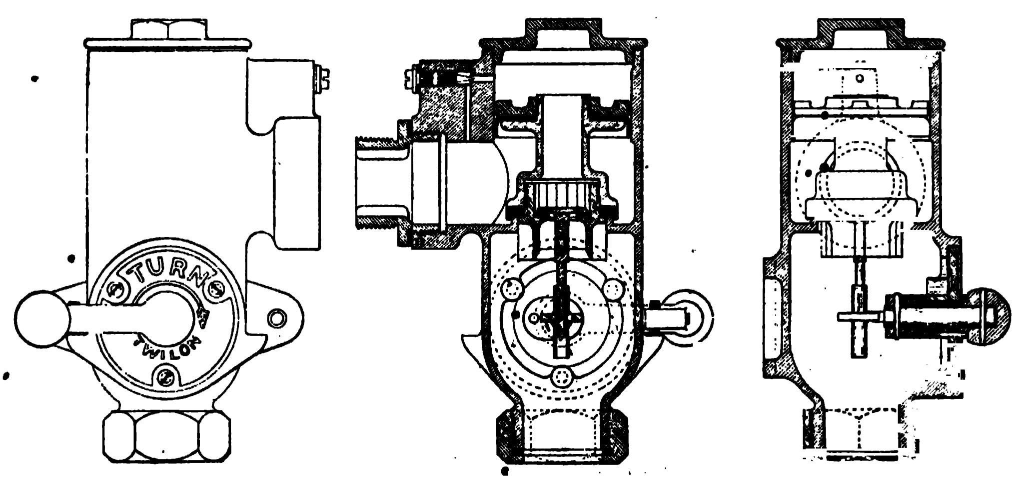


Fig. 4. "Hydrus" valve with stopcock, loose wall flange, and short flush pipe. (*Shanks & Co. Ltd.*)



FRONT ELEVATION SECTION THROUGH INLET SECTION THROUGH FRONT PLATE

Fig. 3. "Twilon W.C. Flushometer" valve, providing instant flush, regulated to suit any head of water, with reducing nipple to fit pipes under 1¼ in. (*Davis, Bennett & Co., Ltd.*)

FLUX. Most metals are found to combine with oxygen and such combination is increased when the necessary heat for soldering, brazing or welding is applied —oxygen being taken up from the atmosphere. Gases from a flame used for heating the joint may have a deleterious effect also. A flux is used to protect the surfaces from oxidization, to neutralize the effects of heat and of the gases in contact with the metal, and to assist the flow of the fused metal over the surface being soldered, brazed or welded. Fluxes are not needed in autogenous welding of lead (lead-burning) or in welding mild steel and wrought-iron.

Fluxes for Soldering and Brazing. Broadly, there are two types: (1) those which merely prevent contact of the prepared surfaces with the air and its oxidizing influence, during the heating and the process of soldering; (2) those which act as the former type but in addition have an actual cleansing effect by dissolving oxide and floating it away (as a slag) from the surface being soldered or brazed (*see* Brazing; Soldering).

Borax is used in hard soldering (*i.e.* silver soldering and brazing). In brazing the solder (or spelter) is often mixed with the borax and applied in granulated form with an iron spatula when the required temperature has been attained, or it may be damped with water and applied as a paste.

Hydrochloric acid, or "spirits of salts," is not used in concentrated or commercial form as a flux. In dilute form it may be employed with advantage in soldering on dirty or badly oxidized zinc or galvanized iron, where the ordinary mechanical cleaning is insufficient owing to pitting, etc. As "killed spirits," or zinc chloride (*see* later) it is a common flux for soft soldering.

Olive oil or Gallipoli oil is used when soldering pewter, Britannia metal, or similar alloys having a low melting point.

Resin. This is usually applied as a powder with added tallow and is used as a flux when tinning brasswork or copper tube, for fine solder joints on brasswork, for brass-to-lead joints, and for the typical capillary soft-solder joints used in low-pressure copper tube work. The resin and tallow may with advantage be melted together and used as a paste.

Sal-Ammoniac (ammonium chloride) is used as a flux chiefly when tinning copper bits (soldering irons) and is considered to give a better and more lasting tinned face. It is also used for soldering copper and iron, and is added to the borax flux when brazing copper.

Special Fluxes. There are many proprietary fluxes which are often advantageous for general work and for special metals and alloys. Among these are: "Fluxite" (a paste), "Baker's Fluid," "Solder-All," to name only a few. Fluxes may be incorporated in the solder, such as resin core or acid flux in sticks of solder. The latter can be had in tubular form with a core of flux running through. For use with their "Full Way" copper fittings, Ideal Boilers and Radiators, Ltd. supply a non-corrosive flux in paste form (*see under* Capillary Joint, page 210) as do also The Yorkshire Copper Works, Leeds.

Tallow or "Touch" is used as a flux for lead when making the typical wiped solder joint, after mechanically removing the lead oxide by means of a shavehook from the surfaces to be soldered.

Zinc Chloride—often known as "Killed Spirit" (*i.e.* hydrochloric acid "killed" by dissolving chips of zinc in it). This is used chiefly for tin-plate, new sheet zinc and galvanized iron. For clean work it should be filtered, and a little water added for tin-plate. Zinc chloride should not be used for tinning brasswork to be soldered by a plumber, for wiped joints, for electrical work, or for capillary soft-solder joints, as it is slightly corrosive. Moreover, it has been found in practice that a more lasting result is obtained by using, for example, a mixture of tallow and resin when tinning a soldered surface to which adherence is made.

Fluxes used for soft soldering should evaporate, and excess flux on a finished joint should be wiped off while warm. When a spirit or acid flux is used, all traces of the flux should be washed off with warm water as soon as the joint is finished.

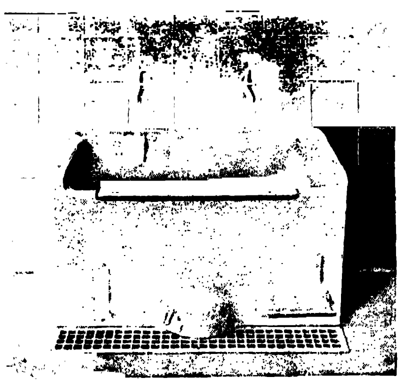
Welding Fluxes. Fluxes used in welding (*see* Welding) are sometimes incorporated in the filler rod. For instance, elements having a great affinity for oxygen and the blowpipe gases are included in the rod in very definite and precise proportions—such as silicon in cast-iron filler rods; phosphorus for

copper and bronze; also traces of aluminium. The flux for welding aluminum must be very energetic, owing to the affinity for oxygen which this metal has when in the molten state. Such fluxes are best obtained from firms manufacturing well-known proprietary brands—*A. C. Martin, M.R.San.I., R.P.*

See also Joints: (1) Lead; Pipes: (3) Jointing Brass and Copper.

FOAMING (of Boilers). *See* Priming.

FOOTBATH. Footbaths are used in such places as schools, factories and public swimming baths. Usually they are of white glazed fireclay, and this is the best material, although vitreous enamelled cast-iron footbaths can be obtained. The fittings are made for installation as units or in ranges, and in the latter case the joints should be of the overlapping type. Sizes range from 18 in. wide, 20 in. back to front, and 12 in. high to about 30 in. wide, 26 in. back to front, and 18 in. high.



FOOTBATH. White glazed fireclay footbath fitted with teak pad on front roll and hooded waste discharge.
John Bolding & Sons, Ltd.

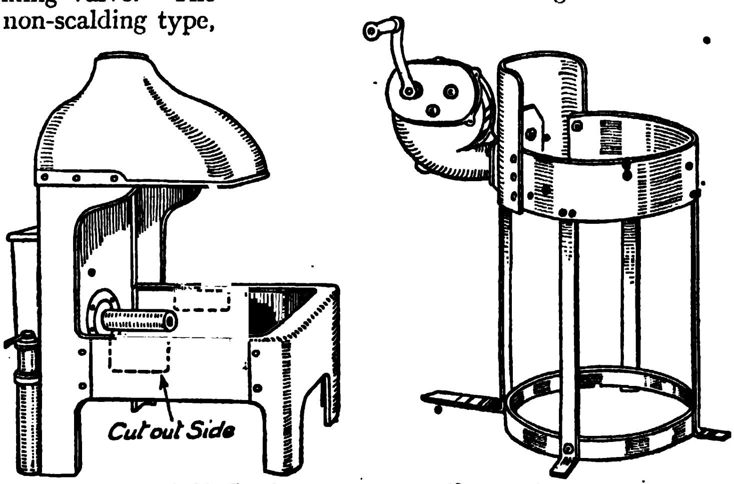
Footbaths must be fitted with overflows; these may be of the weir type, or a combined standing waste and overflow may be used. The hot and cold supplies are separate from the bath, so that any desired type may be fixed—either individual taps or a mixing valve. The latter should be of the non-scalding type, and the usual precautions regarding equality of water pressures and flows should be observed. The waste connexion should be treated in a similar manner to that of an ordinary bath. Often footbaths are made with a low front to make it easy for stepping in and out. In any case the back and sides should be high, to prevent splashing.

A typical modern white glazed fireclay footbath is shown in the illustration. This is fitted with a teak pad on the front roll, and a hooded outlet discharging over the floor grating.—*L.C.C. Rayner, A.I.E.C.*

FORGE (Plumber's). The plumber of today is often called on to make small forgings (such as gutter hangers, or slips), or to make bends on wrought-iron heating or gas tubes. Therefore he needs a forge; this may be a permanent one of the blacksmith's hearth type, or a portable circular forge with fan. Both of these are described.

The writer has found by practical experience that for permanent use the cheap wrought-iron forge with a hand-operated rotary fan is not very successful; there is trouble due to the fan not being rigidly supported, and the bottom of the forge burns out very quickly. The best type of forge is the cast-iron blacksmith's hearth (Fig. 1), either with the old-fashioned water tue-iron and bellows (with back draught), or with a fan driven by an electric motor and arranged to give a back draught. Back draught means that the air forced into the fire, instead of passing through the bottom of the forge, enters through a nozzle in the back.

A convenient size of forge is one about



FORGE. Fig. 1 (left). Fixed type of plumber's forge in c.i., to be used with either fan or bellows. Fig. 2. Portable back-blast fan forge, fitted with hand-operated fan, dust-proof gears, oil bath for gears; fitted hood obtainable.
Abbott, Birks & Co., Ltd.

3 ft. square, having sides about 9 in. to 10 in. high, and standing on four legs, the height from the floor to the top of the sides being about 2 ft. Over the top of the forge is a canopy to take off the fumes; this is usually fixed about 2 ft. above the top of the forge sides and is 2 ft. deep, thus giving the forge an overall height from floor to top of canopy of 6 ft. It is advisable to connect this forge into a brick flue, rather than to a metal chimney; a metal chimney will cause the smoke to pour out of the canopy until the metal chimney gets warm.

Portable Forge. This is one similar to those used in shipyards, and may be readily transported from job to job. It consists of a circular wrought-iron pan about 21 in. in diameter, mounted on four legs which give it an overall height of about 3 ft. Since it is intended for use in the open air, or on unfinished buildings, this forge has no canopy, the fumes being allowed to escape direct off the fuel into the air. The draught is at the back and is supplied by a ball-bearing, hand operated rotary fan which is securely bolted to the pan (Fig. 2).

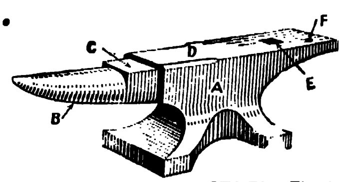
A forge as purchased is not very suitable for heating long lengths of pipe. A useful tip is to cut a semi-circle in each of the two sides of the pan; this enables the worker to press the pipe well down into the fuel and to keep it covered while being heated; even heat is required all round the pipe to give a good bend.—*J. Malpass, M.R.San.I.* *See* Pipe Bending.

FORGING: ELEMENTS OF SMITH'S WORK

By W. F. Hough

The plumber and heating engineer generally has access to a forge, and uses it for pipe bending, etc. Therefore, a knowledge of simple forging is an advantage in shaping and fashioning stays, brackets and other supports, avoiding delay and ensuring in some cases a better job being turned out. See Forge; Pipe Bending.

A knowledge of elementary smith's work is of value to the plumber, who already utilizes a forge (*which see*) to heat up pipes for bending. Some of the commonest operations are here described, with notes on the tools used. Practically speaking, the methods described for the hot working of the metal can be applied to cold bending, except that the metal cannot be bent to such a sharp angle when cold without risk of cracking at the bend. Wrought-iron should seldom be bent cold, except when the bends are in the nature of a long curve, and free from any suggestion of a right-angle bend.



FORGING IRON AND STEEL. Fig. 1. Anvil, standing on solid base, about 26 in. in height. For description of parts as lettered, see text below.

The Forge. This is described in the opposite page under its own heading. The fire can be lighted with paper and pieces of wood in the usual way, and the bellows or blower worked gently to draw up the fire as soon as it has taken hold. The fuel should be coke or fine slack coal, the former for preference, as there is less smoke. It must fill the pan and be heaped up in the form of a mound, and as the bellows are worked the air will escape through the fire and form a crater of intense heat. It is then known as a clean fire, and is in the required condition for working.

The iron is placed inside and covered with more fuel to exclude the cold air. The surrounding coal may be damped slightly from time to time. The clinker and slag are raked out from the fire, and new coal added as required. The metal should always be covered with the fuel, as this saves much waste and ensures a good heat. The metal is withdrawn occasionally to ascertain the progress of the heat, and as soon as the iron is a good bright red heat, generally known as a cherry red, it is in a fit state to work.

Tools. The anvil should be not less than 1 cwt. in weight, and heavier for preference. It should stand on a solid base, and the top of the anvil should be about 26 in. above the floor. The parts of an anvil are lettered as follows in Fig. 1: A is the body, generally wrought-iron; B is the horn (or beak iron), and C the base of the horn; D is the face, of hard steel welded to the body; E is the hardie hole, and F the pritchel hole. The hardie hole is used to hold the shanks of the tools, and the pritchel hole to permit the

passage of stock metal while making bolt heads and the like. The two side edges of the face are often rounded off for a short distance from the horn in order to facilitate the bending of rod metal.

Anvils can be obtained in various sizes, but the worker should select one that has a fairly regular tapering bick-iron, as this will be found more useful in many ways than an anvil with a short stumpy bick-iron; also be sure to have one that has a square and a round hole at the tail end.

FORGING IRON AND STEEL. Fig. 2. Tongs fitted to the job and holding the work tightly (see also Figs. 3 and 4).

A good strong vice of the regular blacksmith's type will be needed (*see* Fig 14), and must be well secured to the bench and floor.

Tongs. A pair of flat-jawed or open-mouthed tongs and a pair of hollow-jawed tongs can be made or purchased. Their form is shown in Figs. 2–4. To hold the work properly the tongs should be fitted to the thickness of the job by heating the jaws to a red heat and hammering them together while a piece of the metal to be held is gripped between the jaws, as in Fig. 2. The tongs should not be left in the fire.

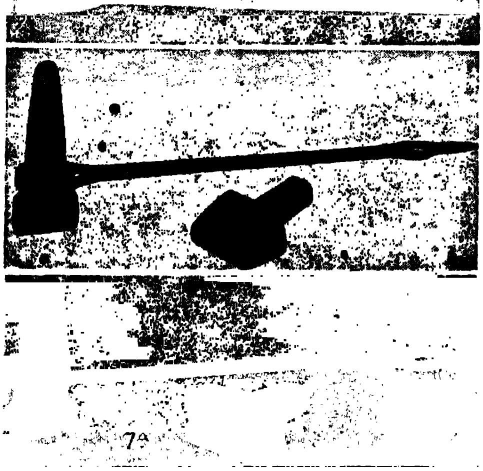


Fig. 3. Round or hollow-jawed tongs. Fig. 4. Open-mouth tongs. Fig. 7. Top and bottom fullers. Fig. 7A. Top and bottom swages or rounding tools.

Hammers. Hammers required are the sledges and hand hammers, and the weights of these vary according to the class of work being done. The sledge hammer can weigh anything from 6 lb. to 14 lb., but for ordinary work one about 9 lb. or 10 lb. is quite heavy enough. The hand hammer for regular use should not weigh more than $1\frac{1}{2}$ lb. (but one about $2\frac{1}{2}$ lb. will be found very useful on some jobs), and should be a ball-pened one. The handle should be somewhat longer than the ordinary hand hammer, the usual length being about 18 in. over all.

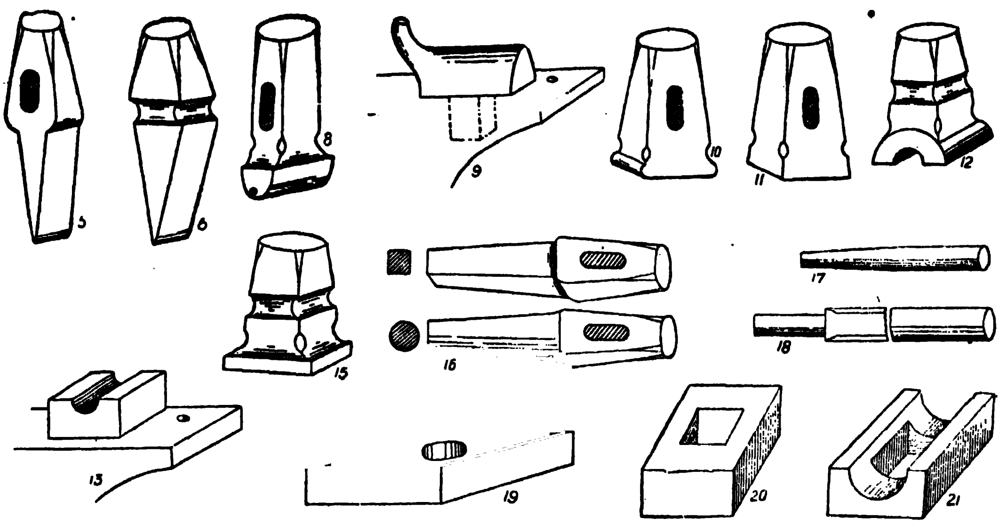
Chisels, Fullers, Flatters, Swages. With the exception of the hand hammer, the hot and cold chisels (Figs. 5 and 6) are the ones most used. As their names imply, they are used for cutting up hot and cold iron respectively. Figs. 7 and 9 show top and bottom fullers, Figs. 10 and 11 the round-edge and square-edge set-hammers, Figs. 7A, 12 and 13 top and bottom swages, Fig. 15 the flatter, Fig. 16 the round and square punches, Figs. 17, 18 and 19 the drift, mandrel and bolster respectively.

The tools that should be purchased as occasion demands are a flatter, one or two fullers, and one or two rounding tools or swages. Flatters, fullers and swages require an assistant to hold the tools (*see* Figs. 47–48). The shank of the bottom tool rests in the hardie hole of the anvil, as shown in Fig. 9.

Rod Punches. Rod punches (Fig. 16) can be made to various sizes and to suit any shape of hole it is desired to punch, and should be made of cast-steel. Drifts (Fig. 17) are simply short lengths of metal made tapered to various sizes and sections, for driving into the punched hole, usually for enlarging and for cleaning-up purposes.

Bolsters. Bolsters are made in various styles and sizes; in a general way they consist of a piece of metal with holes through it to take a particular size and shape of metal either with a flat surface or a concave one, as Figs. 19 to 21.

Mandrels. These (Fig. 18) are practically drifts with a length of metal attached for handling; they are used for passing through hollow forgings so as to make them solid and keep the hole true while the outside is being forged to shape



FORGING IRON AND STEEL. Figs. 5, 6, 8–13, 15–21. Tools: (5) hot chisel; (6) cold chisel; (8) top fuller; (9) bottom fuller (*see also* Fig. 7); (10) round-edged set-hammer; (11) square-edged set-hammer; (12) top swage; (13) bottom swage (*see also* Fig. 7A); (15) flatter; (16) square and round punches; (17) drift; (18) mandrel; (19) bolster; (20) flat bolster; (21) half-round bolster. (For Figs. 7 and 7A *see* page 438.)

and size as, for example, nuts, loose collars, small rings or bushes.

Management of the Forge. A few notes on the general routine of smith's work are here given. The worker should first go through the whole job and mentally see the job finished before he starts it.

By so doing he will know just what tools will be required and have them ready to hand for use at the right moment. He should also have as clean a fire as he possibly can and plenty of firing on the hearth, for the simple reason that too little firing is often the cause of a bad weld, owing to the fact that the parts cannot be covered to retain the heat, and the result is that instead of a soft welding heat, only a hard frizzling heat is obtainable, with which it is impossible to make a good sound weld.

When getting the welding heats, such should be of a uniform heat all through the part that is being welded; what is meant by this is that up to a certain size of stock the welding heat can be obtained without any particular regulation of the blast, but for larger sizes it will be found that if the blast is not regulated, only the outside of the metal is at the welding point, and the result is that although it may be welded together and appear sound, it is not a good weld, as the centre part of the metal is not joined together and would in some cases be dangerous and unsafe. This is more noticeable when getting welding heats on steel than on iron.

To get over this difficulty use a steady blast until the metal nearly reaches the welding point (in the case of larger-size stock it is advisable to stop the blast altogether for a few seconds so as to allow the heat to soak), then force the blast gradually and bring to the welding point as quickly as possible. Also, whilst getting the welding heat do not let the parts lie in the one position in the fire; they should be continuously moved, turning over backwards and forwards and occasionally drawn out of the fire to see how the heat is progressing. If found that the edges of the scarfe are hotter, or nearly at the welding point before the other part of the weld, the point of the scarfe should be dipped in some clean sharp sand, or a little can be thrown on by hand; this will retard the heat and keep it from burning whilst the other part of the weld reaches the welding point. Generally iron at the welding point looks white and dazzling, dead soft steel looks just white, and harder steel shows a kind of orange yellow and looks as if grease is running over it.

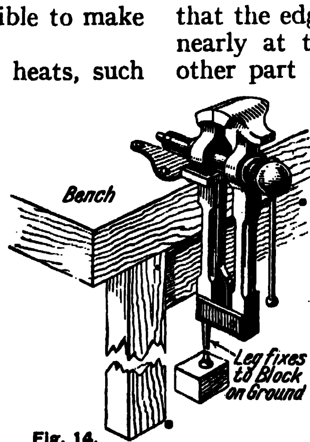
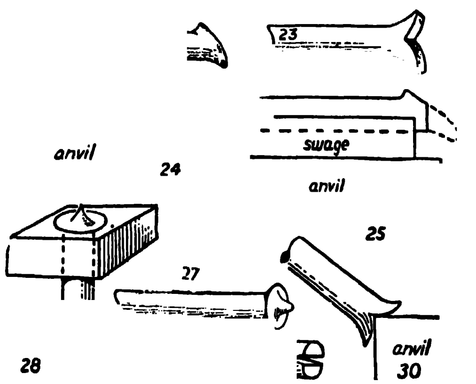


Fig. 14.
Blacksmith's type of leg vice.

Scarfing and Welding. There are several kinds of scarfes used when welding two pieces of metal together: the principal ones are described and illustrated in this and the following page. The selection of the scarfe to be used will depend to a great extent upon the kind of weld, and to a lesser degree upon the desired shape of the forging. The application of the various scarfes will now be shown.



FORGING IRON AND STEEL. Figs. 22–30. Scarfing and welding: (22) lip scarfe; (23) V-scarfe; (24) forming lip scarfe on square or flat-section metal placed on edge of anvil; (25) round- or oval-section metal scarfed in bottom swage; (26) upsetting and scarfing tool for shaping lip scarfe on bars; (27) mushroom scarfe; (28) forming the mushroom scarfe in a bolster; (29) metal split for V-scarfe; (30) forming V-scarfe on corner of anvil.

The weld generally used is the lip scarfe (Fig. 22), which can be used for any kind of lap weld. The mushroom scarfe (Fig. 27) which is used for stump welding, and the V-scarfe (Fig. 23)—used in a somewhat similar manner as the stump weld—are other types of weld. When a butt weld is made no particular kind of scarfe is required.

When forming the lip scarfe the metal that is to be welded together should be thickened by jumping-up, well hammered back on the top edge, and the scarfe made by using the top fuller. In forming the scarfe on flat- or square-section metal, the scarfing should be done on the edge of the anvil as shown by Fig. 24; when scarfing round- or oval-section metal it should be done in the bottom swage as given by Fig. 25.

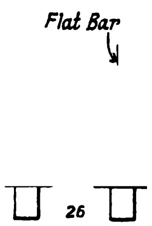
Upsetting and Scarfing Tool. This tool (Fig. 26) is useful for upsetting, and for shaping a lip scarfe on either flat, square, or round bars. The tool steadies the bar (*see* diagram) when struck on end; and the high side keeps the bar from bending near the upset. Several sizes of this tool should be kept for bars of different thickness.

With the mushroom scarfe (Fig. 27) the metal is thickened up at the end, passed through a bolster, and the scarfe formed either with a top fuller or a bob punch (*see* Fig. 28).

In forming the V-scarfe (Fig. 23) the metal is thickened up as for the stump weld, split down with the hot chisel as in Fig. 29, and then the ends are hung over the edge of the anvil and the scarfes formed as in Fig. 30.

With regard to a butt weld no scarfe is required, the only preparation being to make the ends square where the join or weld comes.

It is inadvisable in scarfing or welding to make the scarfe edges too thin; there are two reasons for this: first, the edge is liable to get overheated and burnt before thicker part attains welding heat; and, secondly, there is considerable waste in getting the welding heat, so much so that when the heat is taken out it will be found that half the scarfe is gone, hence making it more difficult to make a sound and clean weld.

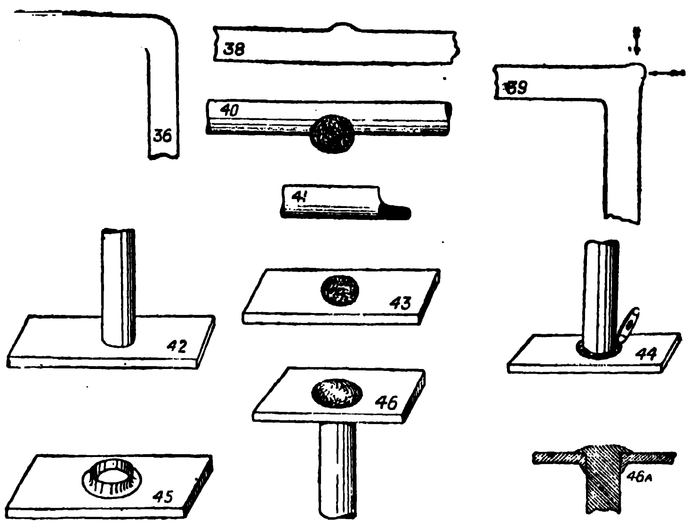


Another important point is that scarfes should have a slight rounding form at the face as shown in the different examples of scarfes, or at least be dead flat. To explain this, take the ordinary lip scarfe for a lap weld (as shown in Fig. 32).

This indicates that when the two scarfes are placed together, they touch each other in the centre of the weld, and as a natural sequence, when the first blow is given on the weld it will join together at the centre first and so make a solid and sound weld; whereas if the scarfes have been made in any way resembling Fig. 31 the result is that when the first blow is given it certainly will join together at the ends of both scarfes, but in the hammering process that follows there is a tendency to draw the centre parts of the weld farther apart and so a proper solid weld may not be made. It is even more important still that the scarfe should not be hollow crossways. On welding, if dirt gets into such a cavity, it cannot squeeze out sideways and the weld will be unsound.

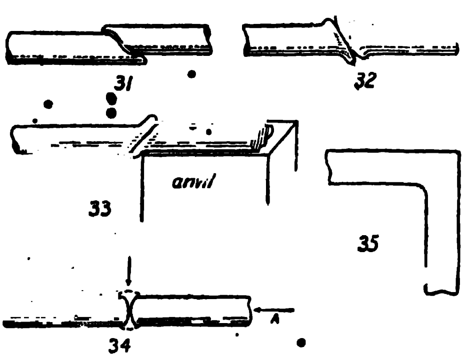
Another point to be remembered when welding up parts is that the bottom scarfe should be placed so that the end of it is hanging over the edge of the anvil, as shown by Fig. 33.

Welding to Length. When making a straight-line lip scarfe weld to exact dimensions, on cutting to length before upsetting, allowance must be made for the wastage caused by scaling during heating and welding. No strict rules can be laid down for this allowance, as some smiths heat and soak the iron much more than others; also the more the two ends are upset the greater is the wastage by scaling, more metal being exposed to the heating. But a rough and ready rule, often used for bars up to about 1¼ in. diameter or thickness, is to allow for wastage an extra length equal to the diameter or thickness of the welded bar. As sizes further increase a somewhat smaller proportion is allowed for wastage, providing that the line of heating is not excessive.



Figs. 36, 38–46. Forgings: (36) round-corner forging; (38) jumping-up metal to form corner shown in Fig. 35; (39) bent corner with excess of metal to be hammered down (indicated by arrows); (40–41) forging T-piece by making lip scarfe; (42–44) welding T-bar to standard; T-bar standard—indentation (to receive vertical bar) made with bob-punch—welding scarfes by set-hammer; (45) circular scarfe made instead of indentation shown in Fig. 43; (46) riveted T-standard; (46A) section through 46.

As before mentioned, no scarfes are necessary for the butt weld, neither does it require thickening-up to allow for waste when hammering together. This is due to the fact that when the blows are given at the end it will thicken it sufficiently to allow for the reducing when hammering together on the top (*see* Fig. 34).



FORGING IRON AND STEEL. Figs. 31–35. Welding and forging: (31) incorrect scarfes which tend to prevent a solid weld; (32) correct scarfes with slight rounding at the face; (33) scarfes on anvil for welding, placed with bottom scarfe hanging over edge; (34) butt weld, which requires no scarfes; (35) right-angled forging.

Forging Methods. Forging is the act of transforming a piece of plain metal into a piece of a different form with regard to its size and shape. This is done in various ways, either by beating out with hammers or with special tools, by jumping-up (Fig. 49); by reducing (drawing down) (Fig. 47); by bending and twisting, and by welding together pieces of various shapes and sizes.

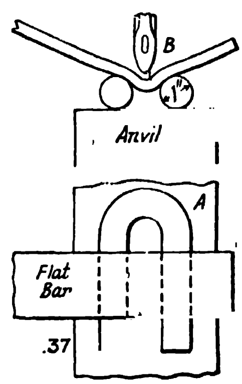


Fig. 37. Bending a flat bar: bar is heated, placed on U-shaped tool A, and fuller is struck as at B.

When welding two pieces of metal that are in line with each other, the lip scarfe (Fig. 22) is the one most generally used; sometimes the V-scarfe (Fig. 23) and sometimes the butt weld (Fig. 34) is used, but this latter only when it is impossible to use either the lip or V-scarfe, or when the metal is of such a size that sufficient force cannot be given to the blows to make a sound weld if the lip scarfe is used.

Fig. 34 shows how a butt weld would be made when two pieces of metal are to

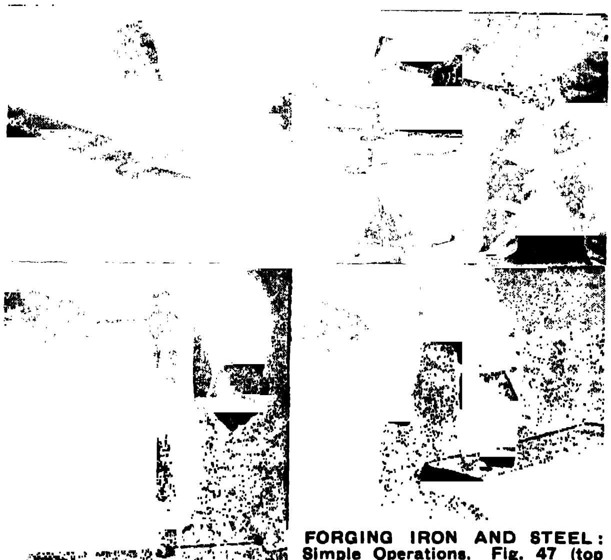
be welded together in line, end to end. The ends are made level and slightly rounding; a soft welding heat is obtained, and the ends are then placed together on the anvil, a few good sharp blows being given as shown by the arrow mark A (Fig. 34). This will cause the weld to assume the shape as shown by the dotted lines. The weld is finished by giving blows on the top and end. The work must be revolved so as to weld in the edges all round.

Corners and Tees. When forging corners (Fig. 35), if the metal is not to be worked up to a square corner on the outside, all that will be required is to get it hot at the point where the corner is desired, cool out at each side of it, and simply bend to the square angle or any other angle that is required; for a corner made by this method see Fig. 36.

Also, when thus bending flat bars on the flat, especially if wide or thick, the simple, U-shaped tool A (Fig. 37) is useful. After heating the bar, give the bend a start with a few blows on the fuller as at B, and the corner can then be easily bent square over the anvil edge, and to a small inner radius if the fullering has been suitable.

Two or three such tools made from 1 in. round bar, and with differing widths between the fork, will deal with bars of varying thickness. If the corner is to be made full up as shown by Fig. 35, get the metal hot, and thicken it by jumping-up, then with the round-edge set-hammer, tool down at each side as shown by Fig. 38, cool out at each side of the raised-up part and bend to the angle wanted; it should then appear somewhat like Fig. 39. Now work up the outsides of the corner by giving alternate blows as shown by the arrow marks.

When worked up square, finish off from the inside of the corner with the round-edge set-hammer, if the metal is of a square or flat section. If of round or oval section, finish off with swages of a suitable size. If desired, a larger-sized metal can be used, so that instead of jumping-up it can be reduced to the shape shown by Fig. 38 before bending. This method is applicable to either round-, square- or flat-section metal, and should one side of the corner have to be of a different size or section from the other, this must be formed accordingly before bending.



FORGING IRON AND STEEL: Simple Operations. Fig. 47 (top left). Drawing down a piece of metal held in tongs. Fig. 48 (top right). Using the swage tools (*see also* Figs. 7A, 12 and 13 in pp. 438-39). Fig. 49 (lower left). Increasing the diameter of a bar. Fig. 50 (lower right). Forming the eye for a bolt hole.

When forging T-pieces, the methods employed are somewhat similar to those used for the corners.

Thicken-up the metal at the point where the T-piece is to be welded, and with the bob-punch form a lip scarfe as shown in Fig. 40; thicken the end of the centre piece and form a lip scarfe (shown by Fig. 41, page 441), weld the two parts together by laying the straight piece on the anvil and placing the T-piece in position on top, work in the scarfes at the inside of the T-piece with either the top fuller or round-edge set-hammer, taking a second welding heat if necessary. Finish off with swages for round or oval sections, and set-hammer and flatter for squares or rectangles.

Where a T-forging consists of different sizes and sections of metal (say a round section stump on a flat crown; *see* Fig. 42) a different method of forging is adopted, and is as follows: thicken up where the T-piece is welded on, and sink an indentation as shown by Fig. 43, using a bob-punch for this purpose. Thicken up the end of the centre piece and form a mush-

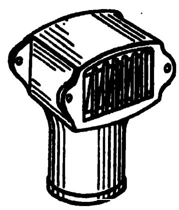
room scarfe. When welding together lay the cross piece on the face of the anvil, indented side uppermost, place the stump fair in the centre, give a blow on the top of the stump so as to get it well home at the root, turn over and pass the stump through a bolster and well hammer down where the scarfe of the stump is situated.

If welded properly, take the hot chisel and cut off the superfluous metal caused at the sides by this operation ; but if the edges of the scarfe are not welded in, narrow the sides in by hammering-up, take a second welding heat and weld in scarfe edges with ball-pene of hand hammer.

Another method is, instead of passing it through a bolster, to weld the scarfes in by the use of a top fuller and round-edge set-hammer as shown by Fig. 44 (p. 441).

In forgings of this description, where the metal that forms the crown is very thin or the crown has to be bent to a small radius at the point where the stump is welded on, it is somewhat difficult in the first case to make a sound weld, and in the second case the edges of the scarfe will break away when bending. To get over this trouble the following method is adopted. Form the mushroom scarfe on the end of the centre piece as before, but use a bolster that has a hole in it somewhat larger than the size of the metal the stump is made of. Now, instead of sinking in an indentation, place the crown over the hole in the bolster that the mushroom scarfe was made in, and drive a sharp-pointed punch through, and so make a hole just large enough to take the stump. This, instead of punching out the piece of metal as when using an ordinary punch, will force the metal through and so form a kind of circular scarfe (Fig. 45, p. 441). Then, while hot at the hole part, place over the bolster and drive the stump through until the head of the stump is down on the flat piece (Fig. 46) and the circular scarfe is underneath. Take the welding heat, pass through the proper-sized bolster, and weld together. The hammering on top will weld in the mushroom scarfe, and the force of the blows will cause the bolster to weld in circular scarfe underneath.

FRESH AIR INLET. Used for admission of fresh air into a drainage system at a point as near to the interceptor as possible. The open area of flap should equal cross-section of pipe. There are four main types: the first is a cast-iron box with spigot end for caulking into the drain or soil pipe socket and having a cast brass front with hinged mica flap (Fig. 1). The second type is made entirely of cast-iron, with double louvre front and double mica flaps (Fig. 2). The advantage of this type is that the flaps cannot be damaged.



FRESH AIR INLET. Fig. 1 C.I. box inlet ventilator for caulking into drain or soil pipe : galvanized, cast brass front, mica flap ; 4 5 in., and 6 in.

In addition to those described there is the "Cregeen" F.A.I. (Fig. 3) used for ventilating the drainage system at ground level. This is a 12 × 12 in. cast-iron box, 6 in. deep, with a hinged ventilating cover. The outlet projects 3 in. into the box and is immediately below the solid part of the cover. Debris entering through the ventilating slots falls clear of the upstand and may be removed from the bottom of the box. The cast-iron bodies of F.A.I.'s should be galvanized to avoid corrosion.

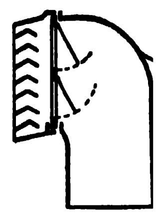
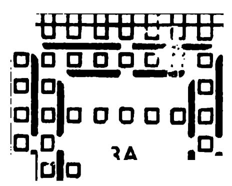
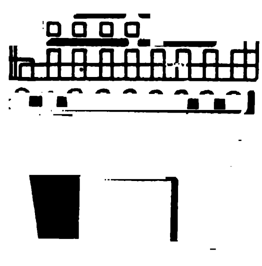


Fig. 2. "Eureka" double louvre front c.i. inlet ventilator with mica flap ; 4 in. only.

Lead and Brass Type. The fourth type of F.A.I. comprises a brass grating soldered to a lead box (Fig. 4). This arrangement is used where appearance is important, as on a stone or brick front.





3B

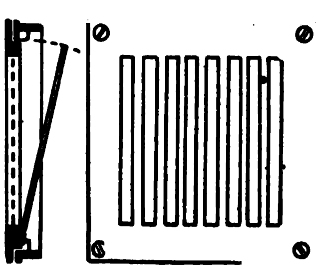


Fig. 3A (left). "Cregeen" fresh-air inlet for ventilating drain system at ground level. Fig. 3B is side view; 4-in. outlet. Fig. 4 (right). Brass grating soldered to lead box, with mica flap shown in section ; 6 in. sq.

Burn Bros., Ltd.

FRICTION AND FRICTIONAL RESISTANCE

By J. W. Cowan, A.M.I.H.V.E.

A clear knowledge of certain aspects of physics is essential for the student and the craftsman. In the present article the effects of friction are explained as they concern the practical work of the plumber, gas fitter, heating and ventilating engineer. See Air Conditioning ; Chimney ; Duct System ; Heating ; Pressure ; also Pipe Sizing.

Friction is the resistant force experienced when one body slides or tends to slide over another with which it is in contact. Friction between solids is known as "solid friction," in contrast to the resistance due to "fluid friction" when one of the bodies is a liquid or a gas. All motion creates friction, and the energy spent in overcoming frictional resistance is invariably converted to heat.

It should be understood (*a*) that the force of friction is passive in the absence of motion or motive energy ; (*b*) that it comes into action immediately there is any tendency towards motion, and (*c*) that it must be opposed by a greater force before inertia can be overcome and initial motion established. It may also be noted that, contrary to the laws governing the performance of other forms of work, the energy expended in (*d*) countering static (stationary) friction and (*e*) opposing kinetic friction (the resistance operative during motion) is lost in the sense that it cannot be recovered by any reversal of the process.

Because friction always opposes motion, it is frequently desirable to reduce such resistance to a minimum. This is very necessary in the design of piping and ductwork installations, and it is also of primary importance in shaft and axle bearings, etc. On the other hand, the successful operation of many machine and pipework components depends entirely upon frictional resistance. Instances of this occur in belt drives, brakes and friction clutches ; and, in pipe work, in all screwed joints and in a number of compression joints of the non-manipulative type designed for use with light gauge copper tube. Web-strap pipe wrenches for polished and plated pipework also depend solely upon friction.

Friction Coefficient. In solid friction the resistance is proportional to the normal or perpendicular pressure between the surfaces in contact. The ratio between these forces is known as the ***coefficient of friction***. This is denoted by the Greek letter μ (*mu*, pronounced *mew*) and has varying values for different substances and differing degrees of roughness of surface. A dry metal-to-metal bearing might have a friction coefficient as high as 0·4. Forced lubrication which would introduce some degree of fluid friction might reduce this to 0·04. In both cases the resistance to motion would be calculated by multiplying the pressure between the surfaces by the appropriate μ value.

Fluid Friction. The laws governing solid friction are relatively simple compared with those controlling fluid friction. Briefly, frictional resistance between a relatively stationary solid and a moving liquid or gas varies directly as (*a*) the relative velocity, (*b*) the area of contact, (*c*) the roughness of surface, and (*d*) the density and viscosity of the fluid.

These variables make direct calculation too cumbersome for everyday practice. For this reason, in calculating the sizes of pipes and ducts we depend upon charts and tables based on empirical formulae provided by independent scientists. For varying conditions these show not a coefficient of friction but a "loss of head due to friction," an expression usually abbreviated to "total friction head." This is commonly taken as being proportional to the square of the velocity, *i.e.* V^2.

It is common knowledge that when a mass has been set in motion a continued application of force is necessary to keep it moving. Three factors combine to determine the amount of energy thus required; namely, (*a*) ***velocity head***, (*b*) ***friction head***, and (*c*) ***resistance head***. In each case the energy expended in countering the opposition is assessed as a loss of initial "head" or pressure.

Because friction in one form or other enters into all three, these resistances are frequently considered together under a general heading of "total friction loss," but a clear understanding necessitates a separate examination of each factor contributing to the total loss of energy.

Velocity Head. The pressure required to maintain the desired rate of flow. This must always be taken into account in calculating air flow in ducts, because of the dissipation of this energy when air is discharged through grilles and exhaust outlets, etc. The same conditions obtain when water is pumped for delivery to a tank. In contrast to this, velocity head may be disregarded when sizing an accelerator for hot water circulation. In such a closed circuit there is no discharge or delivery to bring about a corresponding dissipation of energy, so that it is sufficient to consider only the "friction" and "resistance" heads against which the pump will be required to operate.

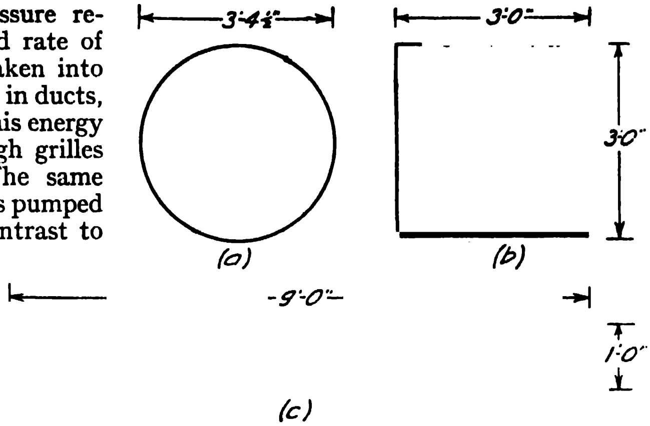
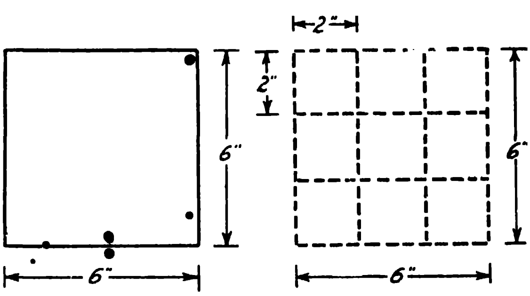


Fig. 2. Sections of 3 ducts, each 9 sq. ft., to show friction areas in contact with air per ft. length: (a) 10·6 sq. ft.; (b) 12 sq. ft.; (c) 20 sq. ft.

Friction Head. The energy expended in countering the resistance to flow set up by every inch of surface with which the moving mass is in contact. Increase in velocity and/or greater roughness of surface will, separately or together, cause added turbulence in the flow and give rise to more internal friction between the particles. In this way either or both will increase the total resistance to motion in the mass. The area of contact has a considerable bearing upon the amount of friction head absorbed. It will be seen



FRICTION. Fig. 1. Relation of area of contact within pipes to friction head absorbed. As explained in text, sixteen (not nine, as might be supposed) 2-in. pipes are required to serve the same duty as one 6 in. pipe.

from Fig. 1 that nine pipes of 2 in. diameter are apparently equal to one pipe of 6 in. diameter, the comparison being made by square pipes for greater convenience of illustration. Because of the vast increase of surface in contact with water in the smaller pipes, the relative capacities must be compared as the square roots of the fifth powers of the diameters.

Thus, $\frac{\sqrt{6^5}}{\sqrt{2^5}} = 15{\cdot}73$, from which it will be seen that, in practice, sixteen 2-in. pipes would be required to serve the same duty as one 6-in. pipe. A further example is seen in the shapes and sizes of ducts of the same cross-sectional area. Fig. 2 shows sections of three ducts each 9 sq. ft. in area. The respective friction areas in contact with air per foot of length are: (*a*) 10·6 sq. ft.; (*b*) 12 sq. ft.; and (*c*) 20 sq. ft., each of which would bring about a corresponding loss of head by friction. *See further under* Pipe Sizing.

Resistance Head. The sum of the pressure losses due to the resistance to flow set up by each change of direction or alteration in shape or size of a pipe or duct. This resistance is entirely independent of friction loss. In preliminary calculation of pipe sizes for heating work an allowance is made for the resistance of fittings (bends, elbows, tees and valves, etc.) by an increase of 33·3 per cent. over the actual length of the pipe circuit. At a later stage this is corrected by the addition of an equivalent length of pipe for each separate fitting or other restriction in the line of pipe. These "equivalent length" factors are based on the resistance of one elbow, and vary with the sizes of the pipes. For instance, the restriction set up by one ½-in. elbow is found to be equivalent to the friction loss of 1 ft. of ½-in. pipe; one ¾-in. elbow equals 2 ft. of ¾-in. pipe. Similarly, a 2-in. elbow equals 6 ft. of 2-in. pipe; and, with certain directions of flow a 2-in. square

tee offers the same resistance as would three elbows, so that 18 ft. of equivalent length of 2-in. pipe would be added to actual length for each 2-in. tee.

Duct Sizing. In duct sizing, each restriction is treated in a manner similar to that just described, and by the use of suitable factors is converted directly to loss of head by resistance. This is always expressed in terms of inches of water column or water gauge (W.G.). In large installations the total pressure loss due to the sum of the velocity, friction and resistance heads seldom exceeds 2 in. W.G. In smaller systems pressure loss or "total friction loss" may be appreciably less than 0·5 in. W.G. The degree of care to be exercised in making these calculations will be appreciated when it is remembered that 1 in. of water gauge represents very little more than half an ounce of actual pressure.

In air conditioning (*which see*), the resistance of the ducts and the filtering, washing and heating apparatus is such that a centrifugal type of fan is employed to deliver air. *See* Fan.

Chimneys. One of the functions of a chimney is to provide sufficient draught to overcome the friction of the flue gases. The chimney must have an area sufficient to permit the gases to flow at a speed low enough not to create more friction than the draught can overcome. The roughness of the sides affects the friction; further, as stated in a previous paragraph, the shape of the passage (the area being constant) is another important factor.

FROST: THE PROTECTION OF PIPES AND FITTINGS

By H. C. H. Shenton, Hon.F.I.S.E., F.R.San.I.

Here information is given about simple precautions and methods of protection that will prevent or substantially minimize damage to water pipes and fittings. By permission, recommendations are quoted from an R.I.B.A. report on the subject. See *further*, on this important subject, under the headings Boiler (6); Bursts; Pipework: (I) Water Pipes in Lead.

Frost may cause injury to any pipe used for the conveyance of water or sewage and may also have a serious effect upon fittings, machines and structures to which water has access.

Water freezes at a temperature of zero Centigrade or 32° F., and the freezing changes the liquid into a solid. While solidifying the substance expands. The results of this change are complete stoppage of the pipe containing the water and an increase of internal pressure (due to expansion of the water at the point where freezing occurs), which is generally sufficient to burst the pipe.

In considering the precautions needed to prevent injury from frost it is necessary to consider the exact conditions of each case, because methods of protection necessary or sufficient in one case may be quite unnecessary or insufficient in another. Common sense rather than standardized method is the surest guide.

Temperatures below zero Fahrenheit have been recorded in Britain on various occasions and will recur, but very serious trouble often results from only a few degrees of frost where pipes are unprotected. The full seriousness of frost troubles is not generally appreciated. As an instance it may be stated that the loss of water through burst service pipes at Leeds during January and February, 1936, amounted to 60 million gallons. This escaped through pipes serving houses.

When pipes are frozen up the consequent stoppage of the water supply frequently entails putting the hot water supply and the heating systems out of use at a time when they are most urgently needed. The stoppage of waste pipe outlets causes baths, sinks and lavatory basins to become useless, and the stoppage of cistern overflow pipes is a common result of frost. Sometimes w.c.'s are put out of action owing to the freezing up of traps and to the formation of ice in soil pipes due to slow leakage of fittings; while intense cold may cause severe contractions and crack the fitting. Flushing cisterns under severe frost conditions may burst, and the blockage of gullies with ice is not unknown; in fact, in the colder climates open gullies outside a house cannot be used.

Another serious possibility is the bursting of hot water radiators. The radiators present a large surface to temperature

effects and are therefore soon affected by frost if they are cold. An unexpected frost, during temporary absence of the inmates of the house, may cause much trouble and inconvenience in this manner by damage ensuing from leakage when the pipes and radiators thaw.

As explained under Bursts, there are also possibilities of danger if the expansion pipe of a heating or hot water system is so arranged that any section containing water is exposed to the action of frost.

A plug of ice may prevent expansion, and the possibility of a boiler explosion exists in spite of the provision of the ordinary safety valve. Valves, hydrants, and other fittings with moving parts may become fixed or inoperative because the moisture or film of water existing at the glands, etc., is solidified by frost and acts as a cement or tight packing, making movement impossible. Frost may also cause the blockage of rainwater pipes and gutters, particularly when water from melting snow or from an overflowing pipe passes slowly along a gutter and into a rainwater head which is already partially blocked. It follows that the gutters and rainwater heads should be inspected periodically and cleared if necessary, to guard against these risks.

PROTECTION OF PIPES AND FITTINGS

The main principles of protection against the action of frost are the avoidance of exposed positions and the casing of pipes and fittings as a protection against temperature changes. (Refer to the relevant section under Pipework: (1) Lead Pipes.) The provision of emptying devices may also be very effective, while the installation and use of valves and stopcocks for the isolation of each branch or section of any water system is good practice and will facilitate repairs.

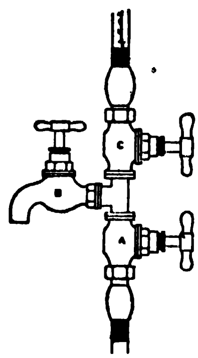
The supply of water into any building can be shut off by means of the stopcock on the main service pipe to the building. It follows that this stopcock should be kept in good repair and that it should be protected against frost. It should also be possible to empty the rising main, and thus an emptying cock should be provided at the lowest point of the system.

R.I.B.A. Frost Report. A "Report on Damage to Plumbing Work Caused by Frost" (price 3d.) has been issued by the R.I.B.A., and certain portions are here quoted by permission.

Stop-Tap. A stop-tap should be fixed immediately the supply pipe enters the owner's land. Another should be placed as near as convenient to the floor, at the point where it emerges within the building.

Draw-off Tap. As near as convenient to the latter stop-tap, a draw-off tap should be fitted so that all pipes which are branches from the main may be emptied by closing the stop-tap and opening this draw-off tap.

The Report recommends the addition of an extra stop-tap, the purpose being to enable water to be obtained from the draw-off tap without refilling the rising main and branches —when the continuance of frost during the day would render them liable to damage. (This device is shown in the accompanying diagram.)



FROST. Safety device: A, usual stop-tap on rising main inside building; B, draw-off tap; C, extra stop-tap to make water available without refilling rising main.

Supply Pipes within Buildings, etc. Supply pipes and all branches to fittings from the supply pipe should, as far as possible, be fixed on internal walls and should be fixed to wood grounds or not directly in contact with the wall, and should be fixed so that they have a fall to the draw-off tap. On no account should water pipes enter the roof space near the eaves, for such a practice not only exposes pipes to risk of freezing but renders them less accessible. All pipes should be laid so that they have a fall and can be emptied by the drain cock.

When it is impossible to run the pipe on an internal wall, a wood backing should be fixed between the pipe and the wall and the pipe should be cased in.

Pipes in Roof Spaces. These should be carefully protected. This can be done by placing them in wooden troughs filled with sawdust, fibre, slag wool, or other suitable insulating material; and great care should be taken that no small section of the pipe, such as may occur at a bend near floor level, remains unprotected owing to the difficulty of arranging the casing. All insulation must be kept quite dry, or it is worse than useless. Where conditions permit, roof spaces or rooms containing pipes and cisterns are heated by means of radiators sufficient to maintain a temperature well above freezing point. Cisterns can be protected by means of non-conducting material and simple wooden casings.

They should also be covered, and every care taken to prevent the freezing up of the ball valves. If the ball valve leaks so as to allow the overflow pipe to drip, this latter pipe is sure to become plugged with ice at the outlet during a frost, causing overflowing of the cistern inside the house.

Flushing Cisterns. In the case of w.c.'s, neither the flushing cistern nor the feed pipe should be near a window or ventilator if it can be avoided, nor against an external wall. Much depends, however, upon the situation of the apartment and upon the likelihood of heating. There should be a flap on the overflow pipe, to exclude draughts which might tend to freeze the water in the cistern itself. Cast-iron cisterns have rounded corners to give extra strength against the effect of frost.

Outside the house all service pipes should have a covering of at least 2 ft. 6 in. of earth. This depth presupposes a sheltered position: in any exposed position the depth of cover should be at least 3 ft. This amount of cover is required in the case of public water mains of larger diameter, and there does not appear to be any good reason for making it less in the case of house service mains, where most leakages occur.

One of the most fruitful causes of trouble is the leakage of draw-off taps. If the tap of a sink, bath or lavatory basin is dripping during a hard frost, an icicle forms at the outlet of the waste pipe and plugs the pipe. Such stoppages can be prevented entirely by keeping the fittings in proper order.

Radiators. With regard to hot water radiators, no radiator should be shut off in time of severe frost. If the whole heating system is kept in operation and if the feed cistern and expansion pipes are properly arranged, there will be no danger from frost; but if any part of the system is left cold so that the frost has access to it, there will be every probability of injury. If a heating system is not to be used in the cold weather, it should be emptied completely. Facilities for emptying exist on any properly arranged system.

Outside Pipes. Standpipes existing in gardens or elsewhere should not be allowed to stand full of cold water in the winter. By closing the stopcock and opening the frost-cock (which latter should be provided in a pit below each pipe), the pipe above ground level can be emptied. Where such pipes must be used in the winter they should be coated with insulating material and provided with a wooden casing, and emptied if a frost of exceptional severity occurs. Where a pipe enters outside ground it should be insulated to a depth of 2 ft.

Hydrants should be provided with frost plugs which open when the hydrant valve is shut and allow the water to drain out after they have been used, thus preventing freezing. Water meters should be arranged with due consideration of the need for protection against the action of frost, and the same applies to any other appliance used in connexion with water service. Where a valve hydrant or other fitting is held by freezing up, it should never be forced to open. The proper procedure is to thaw it by heating moderately.

Where, as sometimes occurs, it is necessary to carry a water main exposed in the open air, it may be protected by suitable insulation. Sometimes for this purpose a pipe of small diameter is placed inside one of larger diameter, so that an air space may occur between the two pipes; the outer pipe is then protected with insulating material and an exterior casing. In the case of pipes of larger diameter somewhat the same result has been obtained by binding slats of wood against the pipe so as to leave air spaces between the slats. The woodwork is then covered with sheet metal casing, and this is again covered with insulating material such as slag wool, which will again be encased.

In the case of a house remaining unoccupied in cold weather the whole water supply system should be emptied and also the heating system. There remains, however, the consideration of water held in w.c. traps, sink traps, etc. This is particularly important in the case of outside w.c.'s in exposed positions, where trouble from frost would be practically certain. Water can be removed from the traps, but that alone would be very undesirable owing to the ventilation of drains and waste pipes into the building. It is, however, possible to overcome the difficulty by partially filling the traps with salt water, which freezes at a lower temperature, or to overcome it entirely by filling the traps with oil.

FROST BURSTS: CAUSES & METHODS OF PREVENTION INVESTIGATED

The account of methods for protection against frost given in the previous pages is complete and sound up to the date of the R.I.B.A. report and has been in no way superseded. Some of the same ground has been gone over again in later investigations, but the subject is of sufficient importance for full presentation. Notes on some recent official pronouncements are given and an extract from the Minimum Specification No. IV of the Institute of Plumbers.

Technical Investigations. Despite the attention focused upon frost precautions in the last two decades, good practice in this important matter is not yet general. In new buildings there is no excuse for not taking the relatively simple and inexpensive steps necessary to reduce to a minimum the risk and waste of burst pipes. A valuable series of investigations was undertaken by the British Non-Ferrous Metals Research Association before the War, and notes from a Paper read by Dr. J. McKeown to the British Waterworks Association, Nov. 1938, are given here by permission.

Established Facts. Dr. McKeown stated that the freezing of water is accompanied by an expansion of approximately 9 per cent by volume. The freezing point is lowered by pressure, but this is of no practical significance since the pressures required to keep water liquid at temperatures materially below freezing point are extremely high. For example, to maintain water liquid at a temperature of 2·5 deg. C. below the freezing point requires a pressure in the water of 2·1 tons per sq. in.; such a pressure would set up stresses in the pipe wall which no water service material could withstand.

When the water in a pipe freezes, the expansion due to ice formation must be accommodated in one of three ways: (*a*) by the unrestricted movement of water along the pipe (for example, back into the main); (*b*) by expansion of the pipe; (*c*) by escape of water from the pipe owing to a burst.

In practice, water pipes not infrequently freeze without any distortion of the pipes, because of the unrestricted movement of the water which accommodates expansion. For instance, in an outside pipe rising to an exposed tap, if freezing proceeds from the tap downwards, the pressure is relieved by the flow of water back into the main. Such effects are frequently fortuitous and not the result of forethought in design. Trouble arises where the freezing water is trapped between taps or between one tap and an immovable ice plug, in which case the pipe must expand or burst.

Much experimental work on materials resistant to frost bursting, or able to withstand expansion due to repeated freezings by reason of superior ductility, showed this is not a practical method, and at the best high ductility can only give a slightly increased life to pipes in frost. Although in a straight run of half-hard copper pipe an ice plug can be moved under presssure, since freezing proceeds farther without distortion than in a lead pipe, in practice the advantage is limited.

In fact, frost bursts cannot be prevented by improvement in pipe materials. *The installation should be so designed that water in the pipes does not become cold enough to freeze or, if it does, high pressure cannot be set up in any length of pipe.*

Conclusions of the Investigation. (1) The material of a pipe is of secondary importance as compared with installation layout. The behaviour of different materials depends on the condition of freezing, and no material can be recommended to avoid frost bursting under unsatisfactory conditions.

(2) Where it is impossible to avoid installing a water pipe in a position which might result in freezing, the pipe should be protected by wrapping or boxing-in (as by wood casing) or both. The best type of protection depends on the conditions and was not studied in this investigation. The value of still air, and the importance of keeping dry any wrapping used for this purpose are well known.

(3) Pipes which are exposed to frost are more liable to burst if freezing proceeds along the pipe towards a closed tap or stopcock. In cases where the complete prevention of freezing is impossible, protection should be so arranged to ensure that freezing proceeds towards an open tap, main, or supply tank.

Thus the only completely effective method of avoiding frost bursting is to prevent the formation of ice in water

pipes, though damage from freezing may be minimised.

Official Notes. Post-war Government publications have given attention to this important matter. In the "Building Study, No. 4, Plumbing" (summarised in a supplement to Vol. 3 of this work) the following paragraphs are authoritative recommendations:

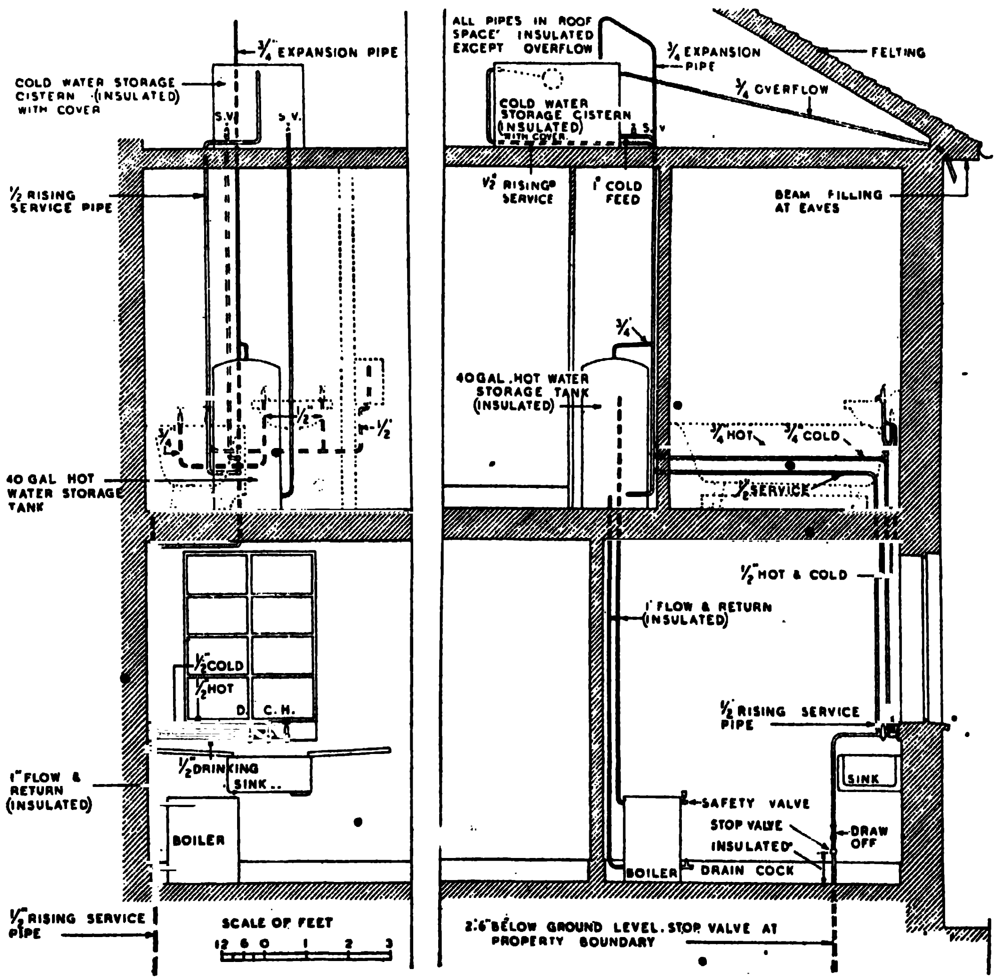
"32. Water-supply piping, cisterns, and tanks should be so located or so insulated that they are adequately protected against frost.

"33. Water-supply systems should be so designed that they can be completely emptied, and convenient provision should be made for carrying out such emptying. (This provision is also useful for easy repairing.)" [*See* Fig. 1.]

The following, quoted from "The Housing Manual" (1944), Technical Appendix (b), is also relevant:

"The protection of domestic water supply systems against freezing has received all too little consideration in the past. Protection can be provided by planning and by insulation. The plan of the building may be such as to lend itself to the secure and economic planning of the water supply system without the use of insulation, but normally even a well-planned system will call for some degree of insulation."

Both are published by the Stationery Office for the Ministries of Works and Health respectively.—*S.G.B.S.*



FROST. Fig. 1. Diagrams from "Building Study, No. 4, Plumbing." Water supply system of house with upstairs bathroom and closet and cold storage cistern in roof. Note interior location of rising service pipe, flow, return, feed, and expansion pipes and storage cisterns and tanks. Where distributing pipes have to run along the inner face of external walls they are supported away from them on clips or pipe boards. In the roof space, lagging of pipes and cistern is shown. This refers to paragraph 32 quoted in the text. Draw-off tap (paragraph 33) is placed above stop valve in kitchen. Draining points not over appliances are avoided

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Minimum Specification Precautions. Additional precautions against frost are given in Para 13 of Minimum Specification No. IV of the Institute of Plumbers, given by permission with illustrations (Figs. 2 and 3) :

13. (i) It is recommended that an emptying

Fig. 2

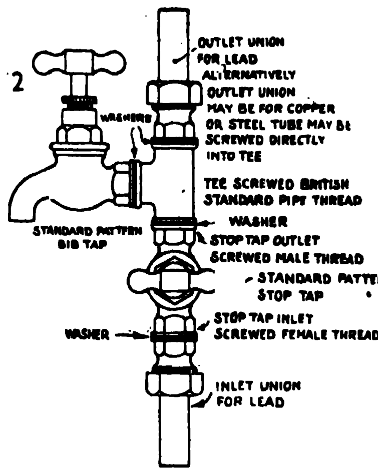


Fig. 3

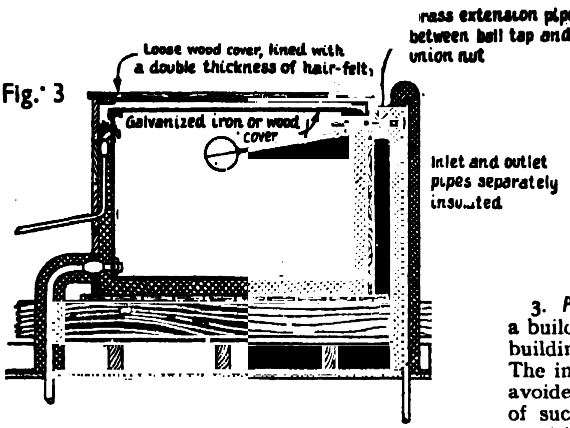


Fig. 2 (above, right). Arrangement of emptying cock above internal stop tap. Fig. 3. Cold water cistern encase in wood and space filled with non-conducting material.

From " Minimum Specification No. IV " of Institute of Plumbers, by permission.

cock should be fixed as close as possible to the internal stop tap on its outlet side to enable the whole installation to be turned off and drained as illustrated [Fig. 2].

(ii) Where pipes are unavoidably fixed in exposed positions they should be protected by being covered with good quality hair felt at least ¾ in. thick, or other insulation. Where the pipe is unavoidably fixed in the external air, the insulation should be protected with a waterproof covering.

(iii) Where storage cisterns are fixed in the roof space or other exposed positions, they should be protected against frost by an outer casing of wood or other material, leaving a space of at least 2 in. all round and underneath the cistern. This space to be filled with non-conducting material and have an additional cover lined with hair felt fixed not less than 2 in. clear space above the normal wood cover. Provision should be made for adequate ventilation to the inside of the protective casing. [*See* Fig. 3.]

(iv) The ball tap inlet should be extended so that the union connection and the water pipe will be outside the wood casing. This allows the water pipe to be separately and more completely insulated. It is not sufficient insulation for the water pipe if the pipe is fixed inside the wood casing, unless the wood casing is boxed out around the pipe 2 in. clear all round. The former method is neater and simpler in construction. [*See* Fig. 3.]

Recommendations for fixing of pipes in Para 3 of the Specification are referred to at the end of Para 13 (quoted above) and are to a certain extent relevant to frost precautions.

3. *Position.* (i) The position of pipes within a building should be carefully selected. In new buildings chases may be prepared in advance. The internal face of an external wall should be avoided wherever possible. For vertical pipes of such position it is preferable to fix on a partition wall. Pipes rising into or dropping from a roof space should always pass through the top floor ceiling at least 6 ft. from the external wall or eaves. All pipes in roof space should be insulated whatever their distances from eaves.

(ii) Where it is not possible to avoid fixing on the inner face of the external wall, wood grounds should be used for fixing of the pipe as an insulation.

(iii) Wrought iron or mild steel pipe lines should terminate within a prescribed distance from the sanitary fitting. The connection from the iron or steel pipe to the fitting to be of lead pipe, having a brass or gun-metal union screwed into the iron pipe fitting and attached to the lead pipe with a wiped soldered joint.

(iv) Pipes should be readily accessible for inspection and repair.

(v) Pipes passing through walls or floors should be guarded by a metal sleeve, permitting freedom for expansion or other movement.

(vi) Where pipes are brought into contact with cement they should be protected by a covering of hessian cloth, hair felt or bitumen paper.

(vii) It is important to avoid dips and air pockets in cold water pipe lines, such undulations create noises and water hammer; they also prevent complete emptying of the pipe when repairs are required, or if the installation is required to be drained from the lowest draw-off tap to avoid damage by frost during temporary vacation of the building.

(viii) When fixing pipes in wood floors, they should run alongside the joists to avoid cutting wherever possible. When cutting the joists for a transverse pipe line the pipes should be fixed near to the bearing of the joints.

(ix) Where pipes are laid across wood floor joists or in wood casings of any description, allowance should be made in the openings to avoid pressure on the walls of the metal pipe and so permit free movement for expansion and contraction of the pipe and to avoid noises due to friction on the joists or casings

FUELS: FOR HEATING AND HOT WATER SUPPLY

By Norman Wignall, A.M.I.Mech.E., M.I.H.V.E.

In this contribution Mr. Wignall briefly discusses the various types of fuel and gives a comparative Table of Calorific Values and other data. Each of the principal Fuels is discussed elsewhere in this work under its own heading (see Anthracite; Coal; Coke; Gas; Oil Fuel), and other information is given in the Boiler group. For the principles of combustion, see Combustion.

A fuel is a combustible substance used to feed a fire. As explained under the heading Combustion, burning is really a process of oxidization, and even the most inflammable or combustible substances cannot burn in the absence of oxygen—generally available in the air, of which it constitutes about 20 per cent. Before a fuel will burn (in normal conditions) it must be ignited, though combustion sometimes starts without outside aid ("spontaneous" combustion). Coal, when heated by the kindling fire of wood, paper, etc., beneath it, gives off a combustible gas that takes fire and produces flame. Once alight, it generates enough heat to continue burning. Coke, on the other hand, being almost pure carbon and containing little volatile matter is harder to ignite and needs more air (greater "draught") to keep it burning. Providing a chimney or flue induces draught—which means that a constantly renewed supply of air is provided to yield up its oxygen for aid in the burning of the fuel. Forced draught is the supply of extra air under pressure to accelerate the burning.

The purpose of burning fuel is, of course, to supply heat: in a stove or open fire, to warm a room; in the furnace of a boiler, to heat the water. Fuels used for these purposes contain mainly carbon, with hydrogen and sometimes oxygen. The carbon and hydrogen are in a chemically combined state. When a fuel is raised to the temperature at which that particular fuel will ignite, it burns—combining with the atmospheric oxygen and generating intense heat as a result of this chemical combination. If sufficient oxygen is present, the gas known as carbon dioxide is produced (CO_2); if, however, insufficient oxygen is present, the poisonous gas carbon monoxide (CO) is formed. Water vapour also is produced as a result of burning fuel. Smoke is merely the unburnt gases plus unconsumed particles of fuel. The so-called smokeless fuels are those which have comparatively little content of volatiles and a high content of carbon (*e.g.* anthracite, coke.) Flame is produced by the burning of combustible gases from the fuel.

Fuels may be solid, liquid or gaseous. The first mentioned are the most familiar, and practically everybody has had a certain amount of experience in their use. Coal may be justly described as our national fuel, and from it coke and gas are also derived.

Solid Fuels. Each type of fuel has its own natural characteristics, and, in the case of the solid fuels, these vary within wide limits. The first and most important consideration with respect to any fuel is its heating propensity, or "calorific value," which is usually expressed in B.Th.U. per lb. and represents the theoretical heat value under perfect combustion conditions. In the case of gas, however, the C.V. is usually given in B.Th.U. per cu. ft.

After the calorific value, two other very important factors are price and combustion efficiency. The latter is largely dependent on the characteristics of the fuel (particularly so in the case of coal and coke) and the efficiency of the apparatus in which it is burnt. Thus, in the case of solid fuels when hand firing under natural draught conditions is practised, the combustion efficiency may be anything from 40 per cent. to 80 per cent.; but where automatic stokers are employed, it should be not less than 65 per cent. and may be anything up to 85 per cent., though seldom above this latter figure.

Coal consists of carbon, volatile matter, and ash in varying proportions. There are three general classes — anthracite, bituminous coal, and lignite. Unfortunately, there is no recognized dividing line between the three groups, and intermediate grades go somewhat vaguely under the terms "semi-anthracite," and "semi-bituminous." The quality really depends on the proportion of pure carbon

in relation to the volatile content and ash. Naturally, in any of the grades, the greater the ash, the poorer the quality. Carbon burns smokelessly, while increase in volatiles tends to produce smoke.

The classification below will serve as a guide, but it must again be pointed out that no definite standardization exists.

with oxygen to form H_2O (*i.e.* water). It is therefore important to ensure that where oil firing is applied to boilers the flue-gas temperature should not drop below the dew point of the gases, otherwise condensation will occur, with deleterious effects on the boiler plates. *See further under* Oil Fuel.

Comparative Table of Fuels

Fuel	Constituents						Calorific Value B.Th.U. per lb.
	Carbon	Volatiles	Moisture	Hydrogen	Sulphur	Ash	
Anthracite	85%–90%	3%–8%	—	—	—	Up to 5%	Approx. 14,500.
Bituminous Coal ..	50%–70%	23%–45%	Up to 5%	—	—	5%–20%	12,500–13,500.
Coke ..	75%–85%	—	5%–10%	—	1%	5%–15%	11,000–12,500.
Oil ..	85%	—	—	10%–15%	1%–2%	—	18,000–19,000.

Below about 10 per cent. of volatile matter the coal is classed as Anthracite.

Pure Anthracite should show a carbon content not less than 85 per cent. with volatiles not more than 8 per cent. and usually not more than 5 per cent. ash.

In the Semi-Anthracites the volatiles increase up to 15 per cent., with a corresponding decrease in carbon content.

Semi-Bituminous coals contain up to 23 per cent. volatiles, and Bituminous anything from 23 per cent. to 45 per cent.

The ash content may vary in any of the grades (apart from the Anthracites) from 5 per cent. up to 15 per cent., or even 25 per cent.

Coke is the residue of coal which has been "carbonized," *i.e.* where practically the whole or a large percentage of the volatiles have been driven off. It contains mainly carbon and ash and burns smokelessly.

A further important factor with all solid fuels is the nature of the ash and its "fusion temperature." Where the fusion point is low, trouble can be expected with clinkering unless special arrangements are provided to overcome it. If the ash has a high fusion point, then it remains in the form of dust or powder after the fuel is consumed, and either falls through the firebars, or allows them to be easily cleaned by agitation.

Oil Fuel. This is a refined form of crude oil as obtained from the oil wells of America, Persia, and Russia. During the process of refining, petrol, lubricating and illuminating oils are separated, the residue being used as fuel. The main constituents are carbon and hydrogen, and it should be noted that during the process of combustion, the latter combines

The table above gives a general idea of the analysis of the four main classes of fuel in common use.

Gaseous Fuel. Town's gas is becoming popular as a fuel for heating boilers on account of the practically perfect automatic operation which it offers. Gas contains a large percentage of hydrogen; therefore the same remarks apply as with oil fuel, but assume even greater importance. The boilers used for gas-firing are very often constructed of corrosion-resisting metal, and particular requirements are necessary in the case of flues connected to such boilers. The hydrogen content varies from 40 per cent. to 50 per cent., methane (CH_4) from 25 per cent. to 35 per cent., carbon monoxide (CO) from 5 per cent. to 15 per cent., and the calorific value may be anything from 400 to 600 B.Th.U. per cu. ft.

Automatic control and fuel feeding can now be applied to any of the foregoing fuels, but in the case of coal or coke a certain amount of handling is always necessary before the fuel enters the storage hopper, as well as cleaning of fires and ash removal. So far as automatic operation is concerned, therefore, gas offers most advantages, with oil a good second, and the solid fuels come last.

Generally speaking, however, what is gained in one respect is lost in another, particularly in regard to economy. Thus the less labour required for attention, the more expensive the fuel, and vice versa. Since the prices as well as the quality of

the respective fuels (with the exception of oil) differ so widely in various localities a choice between those available usually calls for careful consideration, particularly as the economics of the question is almost inevitably the deciding factor.

FUSE AND FUSE BOARD. Fuse is the term applied to a complete device whose purpose is to protect an electrical circuit from possible damage from an excessive current flowing in it (caused for example by a sustained overload or by a fault such as a short-circuit or an earth) by cutting off the supply by the melting, or blowing, of a *fuse element* (commonly known as a fuse wire).

The *Rated Current* of a fuse is that which it can carry continuously without undue deterioration, as stated by the manufacturers, and the *Blowing Current* is that at which the fuse element ruptures—approximately one and a half to twice times the rated current.

Fuse elements are made of standard alloy (63 per cent tin and 37 per cent lead) to protect circuits having a current rating up to 5 amperes, and of tinned copper wire for current ratings from 3 to 100 amperes.

It is no longer permissible to connect an open fuse wire between two fixed terminals. It is carried by a porcelain bridge-piece, either on the surface or semi-enclosed (passing through the holder to prevent scattering of the metal when the fuse blows), or in a glass, ceramic or fibre tube (fitted with metal end caps, known as a *Cartridge Fuse*), and possibly containing a non-inflammable powder.

It has been strongly recommended that cartridge fuses should be made universal.

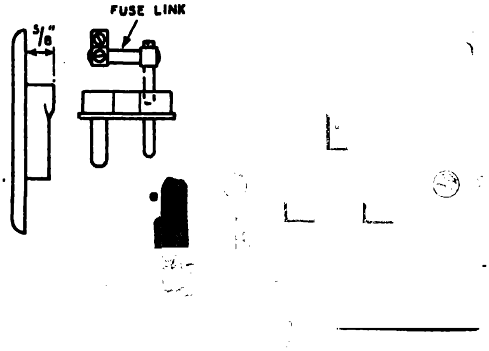
The fuse-element, together with the cartridge or other container, if any, and which is capable of being fitted to the fuse contacts, is called a *Fuse-Link*.

Fuses are forbidden in sockets and ceiling roses, but their use in plugs and socket-outlet adaptors is permitted. Fused-plugs are increasingly used in wiring practice. The plug carries a single replaceable cartridge fuse in the live side only (a two-pin type plug *must* be non-reversible). Fused-plugs are available in 13-amp. rating (Fig. 1).

Current Rating of Fuses. The current rating of a fuse in a final sub-circuit must not exceed that of the smallest conductor (including every flexible-cord not protected by a fuse in a plug or in a socket-outlet-adaptor), it is designed to protect—except that no fuse-link having a current rating of less than 3 amperes need be inserted in any final sub-circuit (except for radio, clock, and other light-duty circuits). Conversely, the rating of any cable or flexible must not be less than the rating of the fuse protecting it. This requirement is often overlooked when portable apparatus is plugged indiscriminately into the first available socket.

The use of fused-plugs or socket-adaptors gives greater scope and flexibility, but in this case the rating of the fuse must not exceed that of the flexible.

Single-Pole Fusing. To comply with I.E.E. Regulations it is essential to know the nature of the supply to which connexion is made. Although it is laid down in general that throughout an installation (except in a branch derived from a cooker control unit), there must be a fuse in each pole, there are certain exceptions, and one, the subject of a recent amendment, is of considerable importance in view of the



FUSE. Fig. 1. Fused plug, standard 13-ampere type with rectangular pins. Above left, fuse link in one pin. Designed for ring main circuits, the outlet of the plug is shuttered.
Courtesy, V. H. Iddon, Ltd.

prevalence of the type of supply concerned. This regulation stipulates that:

Where the neutral point of an alternating current supply is earthed, a fuse, non-linked switch (or circuit breaker) must not be connected in the pole that is connected to earth.

This rule includes all 2-wire circuits connected to a 3-wire or 4-wire system connected to earth, and under these conditions all 2-wire circuits must be controlled by a single pole fuse on the live side.

Distribution Fuse Board. In modern wiring practice fuses are usually mounted in a box constructed of metal or incombustible material (such as a plastic); this

is still referred to as a Board (or Distribution Fuse Board).

A typical circuit connected to a public supply consists of a box containing the service fuses and sealing box (to which the service cables are connected), meter, main switch, and main fuse board to which subsidiary fuse boards may be connected.

The consumer's main switch may be combined with the main fuses. Where such a combination is used in a small installation and the fuses control the final sub-circuits, it is termed a **Splitter-Switch.** Unless the permission of the supply authority is obtained to omit the consumer's main fuse, a combined switch and fuse must not consist of more than 3 double-pole ways, each rated at not more than 15 amperes. The lighting load must not exceed 5 amperes, and the total connected load not more than 30 amperes. But with the supply authority's permission to omit the main fuses there is no limit to the number of ways in the distribution fuse board and no restriction on the connected load.

The switch must be operated from a handle outside the case, which is interlocked with the cover so that it cannot be opened until the switch is at "OFF," when the fuses may be safely withdrawn.

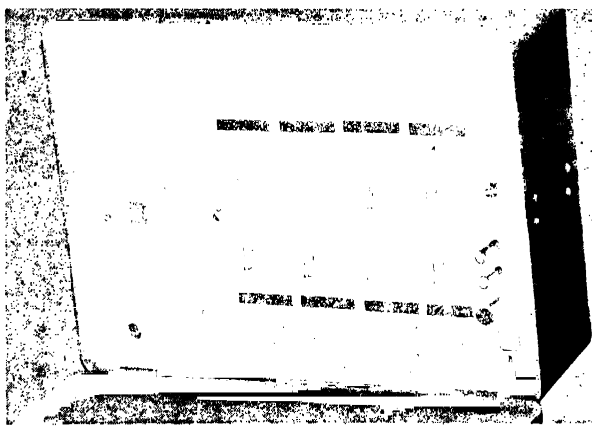
The recommendation embodied in Post-War Building Study No. 11 for a Consumer's Supply Unit have been put into practice. These units are designed to blend with the supply authority's unit consisting of cable-sealing-box, main supply single-pole cartridge fuse (sealed), and a prepayment or quarterly meter.

A type of consumer's unit or fuseboard now available consists of a 60-amp. double pole switch with two 30-amp. cooker and water heater circuits and six 13-amp. circuits for power and light (Fig. 2). The fuses are cartridge, single-pole and of the fused-pin type. Spares are provided. A rotary switch and test lamp enable a blown fuse to be detected at once. The unit is contained in a metal box with an "off" and "on" indicator and is shock-proof, even though the shield be removed and the main switch on.

All metal clad fuse-boards must be earthed by a tinned copper cable of not less than 7/·029.

Every final sub-circuit, unless there is only one, must be connected to a separate way on a D.F.B. A final sub-circuit having rated capacity not exceeding 15 amperes may supply an unlimited number of points provided that the aggregate rating of the points does not exceed that of the cable, and provided that in private houses or residential flats there is not less than one final sub-circuit for lighting for each 1,000 sq. ft.

A final sub-circuit having a rated capacity exceeding 15 amperes must not supply more than one point except in the following cases:



FUSE. Fig. 2. Domestic control unit with cartridge fuses, 60-amp. D P main switch and 2 30-amp. and 6 13-amp. fused circuits.
Courtesy, Dorman & Smith Ltd.

(a) A cooker circuit rated at more than 15 amperes may also carry a socket outlet in the cooker control unit, fused at 5 amperes.

(b) To supply 13-ampere socket outlets, if the following conditions are fulfilled:

Number of Outlets	Max. Rating Fuse	Min. size of Cable
	20	7/·029
	30	7/·036
	30	7/·029*

*If sub-circuit is in form of a wire, with both ends of the cable brought to same terminal on the fuse board.

With a ring circuit (*see* Wiring) it is permissible to take spurs from the ring without additional fusing to serve not more than two outlets per spur, provided that the cross sectional area of the spurs is not less than that of the ring, and that there are not more than 10 outlets on the ring main and spurs combined.—*R. A. Baynton, A.M.I.E.E.* *See* Circuit; I.E.E. Regulations; Ring Main; Wiring.

FUSION (FLAME) CUTTING: BY OXY-ACETYLENE

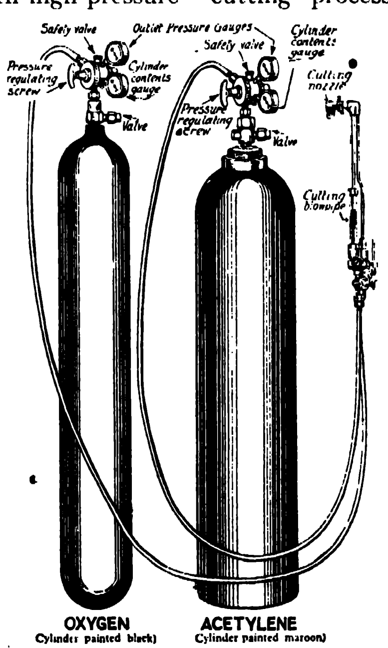
By N. F. Daniel, B.Sc.

Outlining the principles of cutting by the oxy-acetylene blowpipe (for some time known as Fusion Cutting) and describing the plant employed. Notes are included on the application of Flame Cutting to pipework. For other information on the gas equipment, see Acetylene ; Lead-Burning ; Oxygen ; Welding.

The equipment for the oxygen cutting of steel consists of a supply of acetylene either from dissolved-acetylene cylinders or from an acetylene generator ; a supply of oxygen in cylinders ; oxygen and acetylene pressure regulators ; a cutting blowpipe, with a special nozzle ; canvas rubber tubing ; necessary keys and spanners ; welding goggles, and a spark lighter.

On the oxygen cylinder it is necessary to use a pressure regulator which covers a wider working pressure range than is normal for welding. A useful range is given by a pressure gauge calibrated for 10–220 lb. per sq. in. For very heavy demolition work it is sometimes necessary to go up to 400 lb. per sq. in. The normal acetylene regulator can be used as for welding, because acetylene pressures for cutting do not depart very far from those used for welding.

The equipment used with high-pressure acetylene is illustrated by Fig. 1 ; it should be set up in the normal manner, taking the usual precautions that all joints are clean and gas-tight, that the rubber hose is free from grit and dirt, and that there is an adequate supply of both gases.



FLAME CUTTING. Fig. 1. High-pressure oxy-acetylene cutting equipment. Care must be taken that joints are gas-tight and that hose is clean (see *also* text pages 10 and 11 and Fig. 1, page 11).
British Oxygen Co., Ltd.

Principle of Oxygen Cutting. Oxygen cutting may be used for steel of all grades ; and for cast-iron but not for the non-ferrous metals. The principle of the process is that the metal to be cut is heated locally to a temperature above its ignition point (which in the case of mild steel is about 1,000° C.), and then a stream of oxygen is directed on to the hot metal. This causes oxidation to take place, and the heat so produced enables the cutting process to follow continuously and progressively across the metal. As the carbon content in the steel increases it becomes more difficult to cut by the oxygen jet. The difficulties are due to the fact that carbon raises the ignition point of the metal on the one hand, and on the other hand it causes cracking of the metal if cooled down rapidly from its melting point.

Some elements, such as chromium and nickel, also render cutting more difficult, but in general these difficulties may be overcome by pre-heating the steel before cutting commences, and annealing when cutting is completed.

It is now possible to cut stainless steels by a special technique known as the powder cutting process. Briefly, this involves the introduction of a finely divided metallic powder into the oxygen cutting stream, and the fluxing action of this powder, together with the heat evolved by its oxidation, renders stainless steel cutting possible, both for scrap and fabrication purposes.

Further development and research has revealed that this process can now be applied to the oxygen cutting of brass, bronze, copper and other non-ferrous metals.

Oxygen cutting is extensively employed for demolition purposes, while its application for fabricational purposes is a field which is ever widening, and which has a great future in constructional engineering.

For repetition work it is usual to employ an oxygen cutting machine, but for smaller work a hand-cutting blowpipe may be used. The difference between these appliances lies merely in the mechanical contrivances fitted to guide the traverse of the blowpipe around any given shape.

TABLE I.—**Hand Cutting Data. Mild Steel Plate**
Flame Cutting—Oxy-Acetylene

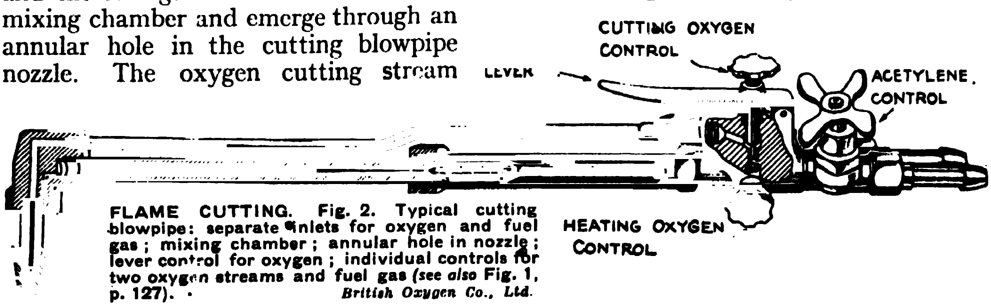
Plate Thickness Ins.	Nozzle Size In.	Cutting Speed Ft./hour	Oxygen Pressure lb./sq. in.	Approximate Gas Consumptions Cub. ft./hr. Cutting Oxygen	Heating Oxygen or Acetylene
¼	1/32	60/80	25/30	30/35	13/19
	3/64	90/115	25/30	70/80	16/19
	1/16	100/125	20/25	110/125	16/19
½	1/32	50/60	30/35	35/40	13/19
	3/64	70/95	30/35	80/90	16/19
	1/16	80/100	25/30	125/140	16/19
¾	3/64	40/50	35/40	90/95	16/19
	1/16	70/90	30/35	140/155	16/19
1	1/16	60/80	35/40	155/170	16/19
	5/64	70/90	30/35	220/245	16/19
1½	1/16	40/60	40/45	170/185	19/23
	5/64	65/85	35/40	245/265	16/19
2	1/16	35/45	45/50	185/200	23/26
	5/64	40/50	40/45	265/290	19/23
3	1/16	25/35	50/55	200/215	23/26
	5/64	30/40	50/55	320/335	23/26
4	1/16	20/30	55/60	215/230	23/26
	5/64	25/30	50/55	320/335	23/26
5	1/16	20/25	60/70	230/260	26/29
	5/64	20/25	55/60	335/360	23/26
6	1/16	15/20	70/80	260/290	29/33
	5/64	20/25	60/65	360/385	23/26

Cutting Blowpipe. Fig. 2 shows in section a typical oxygen cutting blowpipe. There are two gas inlets, one for oxygen and one for the fuel gas. The fuel gas may be, of course, either acetylene, coal gas, hydrogen, or any suitable hydrocarbon. The oxygen stream is divided into two, one portion going to feed the heating stream, and one portion being used for cutting purposes. The oxygen and the fuel gas are mixed in a suitable mixing chamber and emerge through an annular hole in the cutting blowpipe nozzle. The oxygen cutting stream passes through the centre of this annulus. The shape of the flame is shown in Fig. 3, p. 454.

Operation of the Equipment. After setting up the plant the valves on the gas cylinders should be opened and the working pressures set on the regulator. The heating oxygen control valve should be opened, and then the acetylene control valve. After igniting the gas and adjusting the flame to neutral, the control lever for the cutting oxygen stream should be released. By pressing on this lever the oxygen stream may be cut off at will. It is essential to pay particular attention to the size of nozzle used, the distance of the nozzle from the work, and the pressure at the oxygen regulator. Suppliers of cutting equipment will give adequate data on these points and provide guides for maintaining the nozzle at the correct distance. The accompanying table gives useful information in this respect.

Application to Pipework. One of the most important applications of oxygen cutting in sanitary engineering is the fabrication, extension and removal of steel and cast-iron pipework.

If the pipework is to be fabricated by butt welding (either electrical or oxy-acetylene), it is necessary to prepare bevelled edges. An oxygen cutter gives



FLAME CUTTING. Fig. 2. Typical cutting blowpipe: separate inlets for oxygen and fuel gas; mixing chamber; annular hole in nozzle; lever control for oxygen; individual controls for two oxygen streams and fuel gas (see also Fig. 1, p. 127). *British Oxygen Co., Ltd.*

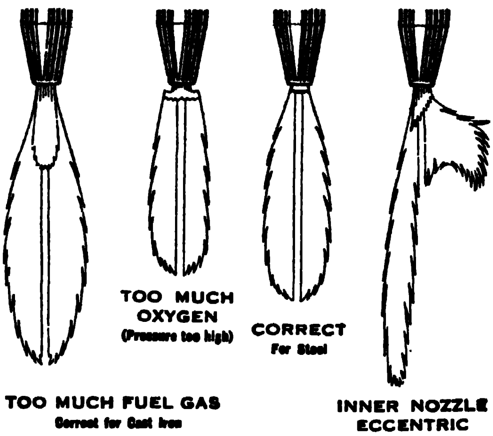


Fig. 3. The oxy-acetylene or other fuel-gas cutting flame: shapes of flame depend on proportions of gases emerging through annulus.
British Oxygen Co., Ltd.

a ready means of doing this. It may be used on site, and any desired length or shape cut to fit.

The oxygen cutter may also be used for the fabrication of pipe bends if it is found that suitable elbows or bends are not available or are too costly. Fig. 4 shows a method of making a bend by cutting and welding (*see* Welding, Pipework).

A portable oxy-acetylene cutting machine can be employed for dealing with pipes. One type is shown in page 783, under the heading Pipe Cutter. This consists of a circular frame, which is clamped to the pipe to be cut, and carries the cutting head. By turning a hand wheel the cutting head is made to revolve around the pipe, and completely to traverse

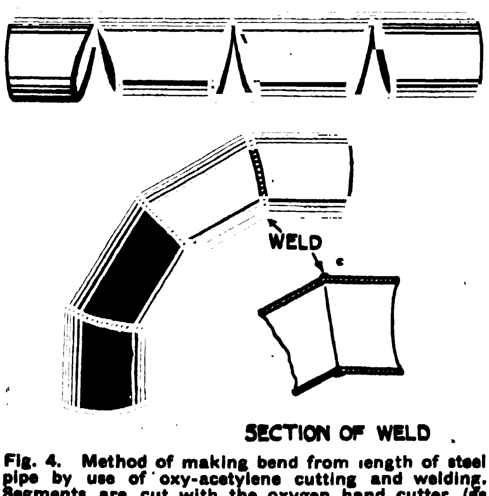


Fig. 4. Method of making bend from length of steel pipe by use of oxy-acetylene cutting and welding. Segments are cut with the oxygen hand cutter (as above) and pipe is then bent.

it, so that the flame can be brought to bear upon the entire surface to be cut.

In connexion with cast-iron pipes, oxygen cutting has been used extensively during recent years. It is necessary to use an excess of acetylene in the flame; and to give the blowpipe a movement from side to side and not attempt to draw the blowpipe in a straight line, as is the case with mild steel.

FUSION POINT. The fusion point of a metal is defined as that temperature at which the metal becomes molten. This definition is quite satisfactory for the pure elements, and the accompanying list (Table I) gives the melting points of a few representative metals which the welder may encounter during the course of his work.

TABLE I.—**Fusion Points**

Metal	Melting Point = °C
Aluminium..	659
Antimony ..	630
Bismuth ..	271
Chromium..	1,553
Copper ..	1,083
Gold	1,063
Iron	1,530
Lead	327
Magnesium..	651
Nickel ..	1,452
Platinum ..	1,755
Silver	961
Tin ..	232
Tungsten ..	3,400
Zinc	419

In the case of alloys, however, the matter is not so simple. Alloys are made up of more than one metal, and usually the effect of adding one metal to another is to change the melting point of the resultant alloy, so that it is lower than that of the constituent metals. If an alloy is first melted and then allowed to cool, and the rate of cooling plotted on a graph, it is found that two or more definite breaks in the rate of cooling occur.

At a certain temperature solid matter begins to separate out and the rate of cooling decreases. This continues until suddenly all the remaining liquid solidifies and the temperature does not drop appreciably for some time. The solid metal then cools quickly.

The range between the temperature at which solidification first commences and the temperature at which solidification is complete is known as the plastic range.

This can on occasions be very useful indeed. A striking instance is the behaviour of plumbers' solder. Plumbers' solder is a mixture of tin and lead; usually in the proportions of two parts of lead to one part of tin. The mixture begins to solidify at about 225° C., but does not set completely solid until 180° C. is reached. This

wide range enables the plumber to wipe the joint as it cools.

The melting range of a number of alloys is given in Table II.

TABLE II.—Melting Range

Metal	Melting Range= °C
Alpax ..	600–577
Brass, 70/30	950–920
„ 60/40	910–890
„ Brazing	870–850
Bronze ..	1050–790
Duralumin ..	650–550
Solder (2 Tin, 1 Lead)	180
„ (1 Lead) 1 Tin)	205–180
„ (1 Tin, 2 Lead)	225–180
Monel Metal	1350–1300
White Metal	440–180

FUSION WELDING. There are many definitions of welding, but in general it is taken to mean a process which involves bringing the metal to be joined up to its melting point, allowing the two edges to coalesce, with or without the introduction of filling material, and then allowing the join so formed to solidify.

It is best to restrict the words "fusion welding" to the processes where electricity or gas brings about the fusion of the metals, and to subdivide fusion welding into electric arc, oxy-acetylene, oxy-coal-gas, etc. The methods of welding which are not included in the group fusion welding are forge welding, resistance welding, hammer welding, etc.

The term "autogenous welding" was once widely used in order to fix the idea that the join was made without the introduction of some other metal or agent. With the widespread employment of welding rods, to supply extra metal to the joint, the term "autogenous welding" is not strictly true, and instead a variety of terms such as "fusion welding," "gas welding" "oxy-acetylene welding," and so forth are used. *See* Welding.

GARAGE DRAINS: SPECIAL REQUIREMENTS

By F. C. Cook, M.R.San.I.

The legal requirements for the prevention of oil and petroleum spirit from reaching the drains. Notes are given on layout and interception arrangements, ventilation, etc., including simplified methods suitable for a smaller garage.

In all large towns, public garages have been instituted primarily for the purpose of storing cars for private individuals who have no garage attached to their own house.

Included in the facilities offered are those of overhauling, greasing and washing the car, while invariably petrol is supplied. Again, with the advent of residential high-class flats, accommodation for the tenants' cars is frequently provided, which generally includes at least a space for car washing; and sometimes petrol is supplied.

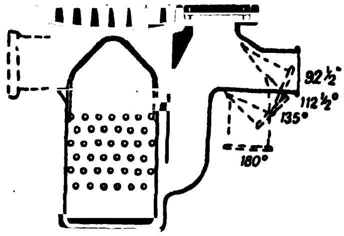
Legal Requirements. The possibility of allowing accumulations of petrol fumes to form within the sewer, thus endangering the lives of the men whose duty it is to work in sewers, is provided against by legislation. The Public Health Act, 1925, Part III, Section 41, defines it as a punishable offence wilfully or negligently to empty, turn, or permit to enter into any sewer or drain communicating with a sewer, any petroleum spirit; while petroleum spirit is defined as (*a*) any crude petroleum; (*b*) any oil made from petroleum, coal, shale, peat, or other bituminous substances; (*c*) any products of petroleum and mixtures containing petroleum which, when tested in manner set forth in the First Schedule of the Petroleum Act, 1879, give off an inflammable vapour at a temperature of less than 73° F. Similar powers are given in the London County Council (General Powers) Act, 1927, which are applicable to London.

The Public Health (London) Act, 1936, Sections 56 and 57, states that it is a punishable offence to discharge into the sewer solid matter such as mud, or offensive liquid matter such as chemical, manufacturing, trade or other refuse, which either alone or in combination with any other matter in a sewer may cause a nuisance or involve danger.

The main point to be considered in garage drains is the interception of the harmful substances such as petrol, oil and mud.

Layout. The general layout for the drains is governed by the size of the area to be drained; and in practice, for a large garage, a main drain usually in heavy iron is installed with branch drains connected by means of junctions. The gully traps to the branch drains are provided with access covers for the purpose of rodding

the branch should it become blocked with grit (Fig. 1). The drains are embedded in concrete 6 in. thick up to half their diameter, and the joints are made with molten lead; an adequate fall is provided to the first intercepting chamber.



GARAGE DRAINS. Fig. 1. Heavy gully in c.-i.: 13 in. inside diam. at top; 12 in. diam. at bottom; 2 ft. deep; 14½ in. diam. by 2½-in.-thick grating; outlet with access cover; w.i. perforated sediment pan with strong handle; 4-in. inlet branches cast on as shown by dotted lines. (*Burn Bros. Ltd.*)

Interception Arrangements. The building regulations governing this class of structure are very exacting owing to the highly inflammable nature of petroleum spirit. The impervious floors, constructed of Portland cement concrete, are laid with gradients so as to allow all fluids falling on them to discharge into gully traps, which are suitably placed in accordance with the area of the floor. The system of drains to which the gullies are attached is laid in a similar manner to those of sewage drains, which, before finally discharging into the sewage drainage system, empty into a triple chamber interceptor for petrol, oil and grit (Fig. 2).

The specific gravity of both petrol and oil is less than water; therefore they will float on the water of the first of the three chambers, to which all the drains from the garage floor are connected. Some of each may be carried through to second chamber during a period of excessive use, such as car or floor washing; while the third chamber provides a further interception for what little petrol and oil escapes the second chamber. It will be noted that deep intercepting pipes are installed in each of the chambers, the depth of one being 2 ft., while two are 2 ft. 6 in. deep, so that the interception has a total depth of 7 ft. The outlet pipe in the first chamber is 6 in. shorter than those in the second and third chambers; this is because the grit and other road detritus freed from the car when washed are retained in this chamber, and only the finer particles are carried through with the flow of water into the second and third.

The size of each chamber is 3 ft. cube to the waterline, which is approximately 170 gallons; ample opportunity is thus afforded for the major portion of the petrol and oil to separate from the water, and for the grit to gravitate before it reaches the bottom of the outlet pipe of the first chamber. The chambers are usually built in 9-in. brickwork with the inside rendered with Portland cement compo, it being necessary that they should be watertight and also airtight at ground level. Each chamber is provided with a double seal heavy cast-iron cover, sometimes with a double cover, or a countersunk top into which floor or roadway material is fixed. *See* Manhole; Cast Iron.

Ventilation. The space between the water level and the manhole cover of each chamber is ventilated by means of 3-in. L.C.C. coated iron pipes which join together above ground level and are carried as one 3-in. pipe to the open air, terminating in a position where the vaporized petrol cannot enter a window or other opening of the building. The reason for joining the pipes together above ground is that if first chamber should become filled with grit to height of outlet pipe, the discharge cannot find an outlet through the vent pipe into the second and third. Such blockage will be evidenced at gully

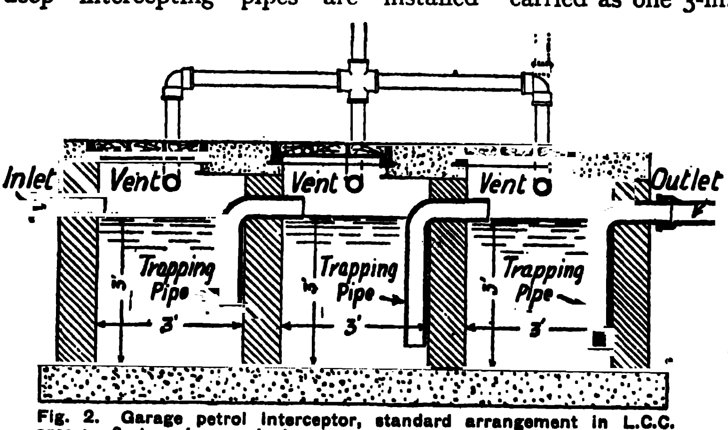


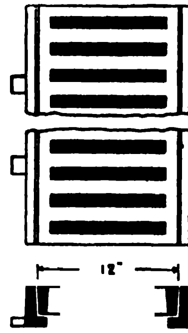
Fig. 2. Garage petrol interceptor, standard arrangement in L.C.C. area: first and second chambers retain most grit and floating oil and petrol; third chamber retains remainder; sizes of trapping bends depend on quantity of liquid expected; covers and frames to suit heavy traffic. Each chamber ventilated by 3-in. pipe. (*Burn Bros. Ltd.*)

outlet of such drain is well submerged.

The specific gravity of petrol vapour is approximately three times that of air, so that the vent pipe should be kept as low as possible to enable diffusion to take place; at the same time the position must be such that ignition of the petrol vapour is impossible: a low percentage of petrol fumes in air forms an explosive mixture, and the entire system of garage drains is invôlved. Hence, all inlets to such drains should be trapped and subjected to periodical flushing, either by floor washing or by being charged with water, so that the petrol fumes cannot be emitted into the garage. Should that condition exist, owing to trapless gullies being installed, an explosion may take place, even by the back-firing of a car; on the other hand, if small quantities of petrol leak from the cars, it remains on the surface of the gully trap water and evaporates; should ignition take place, it is entirely confined to that gully.

Petrol Supply. When a garage has petrol supply pumps attached the area in which the pumps are situated is also drained, and in such a way that spilt petrol cannot flow down the approaches to and from the pump area and into the road gullies. Open channels, covered with strong iron open gratings, are installed (Fig. 3), which discharge into a gully trap situated on the boundary, in cases where the ground on which the pumps are situated is higher than the footpath. These gullies also are connected to the petrol interceptor. The local authorities usually contract to empty the interceptors, using a vacuum plant for that purpose.

Small Interceptors. With the small garage for only a few cars, interception from the drain of the offensive matter can be dealt with by a deep gully trap having a detritus chamber with detachable perforated bucket (*see* Fig. 1). It is good practice to fill bucket with coke for the purpose of retaining oil, which can be disposed of by burning or be removed with trade refuse. It will be noticed that the gully has a very deep trap which assists in intercepting oil and petrol. The size of the gully varies with the number of cars garaged; it can be obtained from 9 in. in dameter (which is suitable for a private house garage) and is fitted with a heavy grating to withstand motor traffic.



GARAGE DRAINS. Fig. 3. Plan and section of c.i. grating over open channel.

The situation of such fitment is in the centre of the "wash-down" in front of the garage, with a slight fall on the garage floor for the purpose of washing the floor if desired.

GAS: (1) PHYSICAL PROPERTIES & BEHAVIOUR OF GASES

By G. A. Hill (Instructor in Gas Engineering, Redhill Technical College) & J. St. Denys Reed

As a preliminary to the discussion of Town's Gas (see second and third articles of this Group) the present contribution gives an elementary survey of the physics of gases. It will be found valuable also to the student of Air Conditioning and Ventilation (*which see*). Gas "laws" are briefly explained: refer also to Boyle's Law; Charles's Law; *and see* Air; Atmosphere; Pressure.

The gaseous state is one of the three phases or states in which matter may exist. In the solid state the molecules composing the matter cannot mov relatively to each other, and are held in mutual contact. Most solid matter may be liquefied by suitable treatment, when the molecules are more or less free to move about within the volume of the liquid. This capacity for molecular movement is measured by the degree of viscosity; ... ''ff, immobile, or viscous, the viscosity is said to be high, and vice versa.

Molecular Movement. Application of heat to a liquid has the effect, among others, of raising the velocity of the molecules; thus the liquid becomes less viscous (*i.e.* more fluid). The molecules are kept within the bounds of the liquid by a force known as surface tension, which prevents the molecules from separating from the mass of the liquid; but at the boiling point the velocity of the

molecules is so great as to overcome the restraining influence of surface tension and the molecules leave the mass of the liquid in the state of a vapour or gas (*e.g.* when water evaporates to steam).

In the gaseous state the distance between the molecules is very great as compared with the size of the molecules; the molecules are then very free to move about and, given sufficient space, the gas will expand (*i.e.* the molecules will get farther apart) indefinitely.

Brownian Movement. The fact that a gas consists of molecules in free and rapid motion has been shown by suspending an exceedingly fine mist of oil in the gas under examination. On viewing the particles of oil through a microscope, they appear to be dancing about in continual movement, which is only explained by the fact that the particles of oil being so small as to be almost weightless are bombarded by the molecules of the gas and thus kept in motion. This is known as the "Brownian movement," and is increased by increase of temperature and pressure and vice versa.

From the foregoing it will be seen that a gas must be very elastic, and it is in fact the most perfectly elastic form of substance. It may be compressed or expanded within its own physical limits indefinitely. Under certain conditions of temperature and pressure, most gases are changed to the solid or liquid form. Two of the gases which are commonly used and more easily liquefied by pressure are sulphur dioxide and carbon dioxide; the later, on being suddenly released from pressure in a cylinder, is immediately changed to the solid form known as carbon dioxide "snow." This substance is used very widely for cold storage purposes.

Gas Leak Detector. An interesting use of the phenomenon that the molecules of a gas are always in motion is that of the leak detector. The molecules of any one gas have a definite velocity at any given temperature: hydrogen molecules have roughly four times the velocity of those of air. If any gas is enclosed in a chamber, then according to the speed of the gas molecules there will be a definite number of molecules in rapid motion and "bombarding" unit area per second. If one wall of the container is porous, a number of molecules of the gas will escape through that wall, depending on the number of impacts against the wall per second. The pressure inside the container will therefore decrease as the gas escapes.

A leak detector consists of a container made in the form of an aneroid (*see* Barometer), one wall (*i.e.* circular end) consisting of a porous plate, while the other end is connected by a system of magnifying levers to a pointer. To detect the presence of a gas lighter than air the aneroid is filled with air: if only air surrounds the instrument the bombardment of air molecules on each side of the porous plate will be equal, and for any number of air molecules passing or diffusing from the aneroid an equal number pass into it; the pointer therefore remains at zero.

If, however, any gas lighter than air (of which gas, therefore, the molecules will have a higher velocity than those of air) surrounds the instrument, then the bombardment on each side of the porous plate becomes unequal, the gas molecules pass into the aneroid at a greater rate than that of the air coming out, the difference depending on the velocity of its molecules compared with those of air. Thus a pressure difference will be set up within the aneroid, the pointer showing the concentration of gas present.

This same phenomenon is made use of in the construction of carbon dioxide and oxygen indicators or recorders, used in the control of flue gases in boilers, furnaces, etc.

Pressure Measurement. High gas pressures are measured by means of a gauge similar to a steam gauge, the pressure acting on a flexible curved and flattened metal tube, and opening out the curve. This moves a pointer over a dial, and is marked in either pounds per sq. in. or in atmospheres (one atmosphere is roughly 14½ lb. per sq. in.). For lower pressures up to, say, 14 lb. per sq. in. a mercury U gauge is preferable and usual; while for lower pressures still a water U gauge is always used. For very low pressures (of the order of 1/100 in. water gauge) modifications of the water U gauge are used. (*See* Pressure Gauge.)

When water is boiled and heating is continued, steam is formed: steam is the gaseous form of water (ice, of course, being the solid form). Steam obeys the gas laws, as all gases do, and may be expanded

or compressed as desired. We compress it in a boiler and use its powers of expansion in steam engines and the like, being a cheap and ready means of converting latent or potential energy (in the form of fuel) into motive power or kinetic energy.

Air, the most common of all the naturally occurring gases, is used in a compressed form for operating road drills, pneumatic hammers, chisels, and in some circumstances for compressed air engines for driving machinery. Water is also raised from deep wells by forcing it up by compressed air. For heating, lighting and power, coal gas is most commonly used. Coal gas is composed of hydrogen, unsaturated hydrocarbons, carbon monoxide and methane, all of which are inflammable when mixed with air, together with small amounts of inert gases such as carbon monoxide, nitrogen and oxygen. It forms a convenient and clean means of supplying heat, light and power.

Gas Laws. Gases to a greater or less extent obey the simple gas laws of Boyle, Charles, Dalton, Avogadro, and Henry. Boyle's law and Charles's law are set out and explained under their respective headings, pages 174 and 224. Boyle's law states that the volume occupied by a gas varies inversely as the pressure to which the gas is subjected. Charles's law states the effect of temperature change upon a gas: the gas increases in volume, for each rise of 1° C., to the extent of 1/273 of its volume; it decreases by 1/273 of its volume for each fall in temperature of 1° C. Dalton's "law of partial pressures" states that in a mixture of gases each gas exerts that same pressure it would exert if it alone were in the vessel in question, so that the total pressure therefore is the sum of the pressures of the component gases of the mixture.

Avogadro's law states that, under similar conditions of temperature and pressure, in equal volumes of different gases there are the same number of molecules.

Going back to Dalton's law, if the gases in a mixture are standing over a liquid, each gas will behave according to Henry's law, just as if it alone were present. Henry's law states that the mass of gas which is dissolved by a given volume of a liquid is proportional to the pressure of the gas.

All matter (including, of course, gases) is made up of tiny particles known as molecules. We have already seen that "Brownian movement" is evidence of the rapid molecular motion of gases. The pressure exerted by a gas is due to the property of infinite and unlimited expansion. When the air pump connected to an air-tight bell jar is operated to extract the contained air, and some air is actually removed from the jar by pumping, the rest of the air in the jar expands so as completely to fill the jar.

Moreover, as the piston of the pump is pulled up, thrusting out air from the part of the barrel open to the atmosphere and producing a state of lowered pressure beneath the piston, air from the bell jar follows up closely, although a considerable quantity may have previously been exhausted from the jar by former strokes. The air left in the jar, it is evident, expands so as to fill the space and goes on expanding indefinitely.

This explains how, when pressure is reduced, the gas increases in volume. The converse is when air is compressed in a non-elastic receiver by a pump, when a given mass of gas is made to occupy considerably less volume than at atmospheric pressure. The effect of temperature rise can be demonstrated by inflating a rubber balloon with air, tying the neck securely and warming the balloon: the latter will expand with the increase in pressure due to increased temperature, so that the balloon "grows bigger."

Another example of the effect of reduced outside pressure may be given: when an aeronautical balloon is being prepared for an ascent and is inflated, say, with hydrogen, a gas lighter than air, it is not completely filled, but space is left for the expansion sure to take place later as the balloon ascends into a thinner (more rarefied) atmosphere and atmospheric pressure grows less.

Practical applications of some of the laws above outlined are to be found in many branches of plumbing, heating and ventilating and are mentioned incidentally in various articles in these subjects throughout this work. The necessarily limited scope of the present article prohibits a fuller explanation here, but the student or the interested craftsman can follow the subject further in a text-book of physics.

GAS: (2) MANUFACTURE OF TOWN'S GAS

By G. A. Hill, M.Inst.Fuel.
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Here, for the benefit of the student and craftsman, the process of manufacturing Coal Gas is outlined and its properties are explained. For further information the reader should refer to Gas (1) and (3); and for the practical aspect see under the heading Gas Fitting.

Gas is obtained from coal by the destructive distillation of the latter in hermetically sealed retorts. This process is also known as carbonization of coal, and the main object is to obtain the maximum of gas and coke in the most economical manner. The methods of producing coal gas are basically the same, varying only in size and shape of retort. It is usual to control the quality of the gas thus made by an admixture of limited quantity of blue carburetted water gas; this is either made separately in a special producer plant, or else the contents of the coal gas retorts are steamed towards the end of the carbonizing period. The chief methods of carbonizing are:

1. Horizontal retorts:
   (*a*) Single ended—hand or machine charging and discharging.
   (*b*) Double ended retorts — machine charging and discharging.
2. Vertical retorts:
   (*a*) Intermittent.
   (*b*) Continuous.
3. Coke ovens.
4. Low temperature carbonization.
5. Complete gasification.

Horizontal Retorts. On a very small gas works, serving a small country district, it is usual to find single-ended retorts which are charged and discharged by hand. The retort is generally ⌓ shaped, and consists of a refractory fireclay tube with an iron mouthpiece and door. Depending on the daily output or "make" of gas required, a suitable number of retorts is built into "beds"—*i.e.* a number of retorts so arranged that they are all heated together by one producer. The latter is situated underneath the retort setting generally, but may be separated, and consists of a suitably shaped furnace filled with incandescent coke. Air and steam are drawn through the firebed, when the oxygen in the air combines with carbon to form carbon monoxide:

$$2C + O_2 = 2CO$$

At the same time the steam combines with carbon to form hydrogen and carbon monoxide.

$$C + H_2O = CO + H_2$$

This mixture of hydrogen and carbon monoxide is known as "producer" gas, and is a cheap low-grade gas very suitable for heating the retorts. The coal is fed into the retorts by hand shovelling or may be charged by a simple machine of the shovel-charger type. The top of the charge is levelled off and the retort door sealed. The temperature is maintained at approximately 1,000° C. for a period of about twelve hours, when the door is opened and the coke raked out. This type of retort can only be comparatively short, for ease of charging and discharging, and is generally 10 ft. long.

Double-ended retorts (generally 20 ft. long) are used on large installations. They are generally ⌓ shaped and, as the name implies, are fitted at both ends with iron mouthpieces and doors. Machine charging and discharging are necessary. Both ends of the retort are opened and the coke pushed out on to a conveyor and quenched with water. The method of heating the retorts is by producer gas as before; indeed, whatever type of plant is in use, heating is always by this method.

The gas, which is very impure, is led away from the retorts by means of off-take pipes situated at the iron mouthpieces at or near the top immediately behind the door. All off-takes go up vertically to the top of the retort setting, then dip down and are sealed into a collecting or "foul" main containing a certain amount of water. The pipes dip into the water, which automatically seals them against gas leakage from the main when the retort doors are opened.

Vertical Retorts. These are tall, narrow rectangular chambers, generally built of silica, tapering gradually from top to bottom, the smaller dimensions being at the top to allow easy discharge of the coke downwards. The bottom of the

retort is sealed by doors in such a way that when the doors are opened the retort is left perfectly clear for the coke discharge. Coal is dropped in by a travelling charging machine through small doors at the top of the retort. The retort is then sealed, and carbonization carried on for 10 to 12 hours. It is usual during approximately the last two hours to steam the retort. By this means a much higher gas yield is obtained and control of quality is also possible; more flexibility is also obtained. The coke is discharged at the bottom into a skip, quenched and hoisted up to storage and grading plant.

Continuous verticals are similar in shape to the intermittent type, but here the coal is fed in continuously and at such a rate that carbonization is complete when any point in the charge reaches the bottom outlet. Coke is continuously extracted mechanically at the bottom of the retort. Steaming is carried out throughout according to the quality of gas required. The gas is taken from the retort by off-take pipes both at the top and bottom, and thence into foul-gas mains in the conventional way.

Coke Ovens. Strictly, coke ovens were designed to produce a hard, good quality coke for metallurgical purposes, the gas being looked upon as a by-product. Although the gas produced is low in grade compared with usual gas works practice, it is now distributed widely for industrial use. Coke ovens are usually run by collieries, so that the gas produced is naturally very cheap, and it is in great demand in the industrial areas surrounding the coalfields. The retorts are shaped similarly to the vertical retort, except that they resemble such a retort turned on one side. The chambers are very much larger.

Low Temperature Carbonization. This process, as the name implies, is carried out at very much lower temperatures than all other processes. The retort is a specially shaped metal container. The gas produced is naturally a rich one, having a high calorific value, but is correspondingly less in volume. The tar produced is rich in oils, and the coke is characterized by its soft texture and the ease with which it is burnt. Taking the gas industry as a whole, low temperature carbonization is carried out only on a small scale, and is a costly process.

Complete Gasification. This is a process wherein the apparatus is similar in principle to a producer—viz. a chamber containing incandescent carbon through which a controlled amount of steam and air is passed alternately, as in a blue water-gas producer. Air is blown through the firebed to recuperate the temperature of the fire, the hot products being used to heat a waste-heat boiler. The firebed in this case is coal, all liquid products (*i.e.* tar) being sprayed on the firebed and subsequently "cracked" and gasified. In this process the only product is gas, the coke being gasified by alternate steaming and blowing. Of course, non-coking coal may be used, which may be of decided advantage.

Purifying Process. From the foul main the hot impure gas containing excess moisture, tar, naphthalene, sulphur compounds, etc., passes through a governor known as the retort house, which maintains approximately atmospheric pressure conditions inside the retorts irrespective of the amount of gas being made. The gas has had a cooling and scrubbing process by bubbling into the liquor in the foul main, but now from the governor it passes to the condensers. These may be just a plain series of pipes cooled by the atmosphere or by spraying water on them, or may be of the compact multi-tubular type in which the gas and the cooling water surrounding the tubes are in counterflow. The effect of the condensers is to bring the gas down to atmospheric temperature, thus condensing the excess moisture, naphthalene, tar, etc.; these latter products are separated and run to suitable storage. From the condensers the gas then passes to the exhausters, used for drawing the gas from the retort house and pumping it through the rest of the purifying train into the gas holders. The gas is pumped from the exhauster to a washer (a vessel containing water, through which the gas passes in very fine streams). This takes out the last traces of light tar fog and most of the remaining naphthalene.

After leaving the washer, the gas is pumped through a scrubbing plant to free it from remaining tar fog, ammonia, etc. The scrubber may be of the static variety: this is a tower filled with wooden grids constantly wetted by a stream of water passing down, the gas passing upwards

and coming into intimate contact with the large, exposed wet surface. Alternatively, a washer-scrubber (combining both washer and scrubber) may be used.

The end of the purifying process consists of passing the gas through large rectangular "boxes" filled with bog ore, a light brown earthy substance containing a high percentage of iron oxide. The remaining impurity now in the gas is sulphuretted hydrogen (H_2S), which in contact with the hydrated iron oxide forms ferric sulphide, ferrous sulphide and water, thus:

$$Fe_2O_3.H_2O + 3H_2S = Fe_2S_3 + 4H_2O$$
$$Fe_2O_3.H_2O + 3H_2S = 2FeS + S + 4H_2O$$

A small quantity of air is pumped through with the gas, in order to revivify the oxide in situ, but after a time it is necessary to remove the oxide and spread it out exposed to the action of the air, when the iron sulphides take up oxygen and deposit sulphur.

The gas next goes through the station meter, and thence to the gas holder. On the larger works the purified coal gas is tested for calorific value and adjusted to the declared calorific value by admixture with a strictly limited amount of blue or carburetted water gas. It is then passed on to the gas holder for distribution as town's gas on the district.

Benzol may be extracted after purifying by a washer-scrubber containing gas oil, creosote, etc.

Coal gas of itself is not inflammable, and has to be mixed with a varying quantity of air before it can be usefully employed. Coal gas is supplied to the consumer at a pressure of approximately 6-in. water gauge, this static pressure being changed into kinetic energy by passing the gas through a small jet just before the burner. An opening is provided just after the jet through which air is drawn, mixed and injected into the burner. This air is known as primary air, and at 6-in. water-gauge pressure only about half the necessary amount of air for complete combustion can be supplied.

To burn a gas mixture in a confined space, it is supplied through a compressor at higher pressure (up to 70-in. water gauge).

GAS: (3) CHARACTERISTICS & UTILIZATION OF TOWN'S GAS

By R. N. LeFevre, M.Inst.Gas E., A.I.Mech.E.

An article for the Gas Fitter and for other craftsmen whose work brings them into touch with gas supplies. It provides information essential to a proper understanding of the practical side of Gas Fitting, dealt with in a later article under its own heading. See *also* Pipes: (4)

In order to appreciate the elementary considerations of what happens when gas burns, it is necessary to know the composition of the gas. This will vary from town to town, according to the type of coal used, the method employed for carbonizing it, and various other local or economic factors. In general, however, the gas will always contain four main combustible constituents, viz. hydrogen, methane, a mixture of other hydrocarbon gases, and carbon monoxide. To burn, each of these gases requires oxygen. When combined with oxygen and burnt, carbon dioxide and water vapour are products of combustion, and they are quite harmless.

A. COMBUSTION OF GAS

Result of Burning Gas. Apart from the formation of the products of combustion, when gas is burnt heat is generated; in fact, this is usually the main purpose of burning the gas, and it is no longer used directly as a flame for illumination. The oxygen required for combustion (*which see*) comes, of course, from the atmosphere, and the burning of gas uses up some of the air in a room. But the amount used is so small relatively that it has no practical significance. There is a lot of air about, and the difficulty, if any, is to exclude unwanted air.

Design of Appliances. A gas appliance must be designed in such manner that it permits:

(i) Adequate entry for the requisite amount of air necessary to burn gas at the rate for which the appliance is intended.

(ii) Proper ventilation of the products of combustion formed when the gas is burnt. It follows that the products must be evacuated from the combustion zone, otherwise fresh air cannot come in to allow the combustion process to continue.

British Standard Specification No. 717, "Combustion Testing of Domestic Ap-

pliances," is intended to ensure a uniform method of testing the combustion of gas appliances, which must in consequence be designed to conform to the requirements of the test if they are to be recommended by the Gas Industry for use by the public.

If combustion is not complete, carbon monoxide will be formed, in addition to the normal harmless products of complete combustion; and since this gas has no smell, its presence in dangerous concentrations may not be suspected. Carbon monoxide is normally present in the atmosphere in minute quantities, and the provisions of the above-mentioned British Standard Specification are such that the amount of carbon monoxide present in the products of combustion from a gas appliance shall be actually less than the normal concentration in the atmosphere.

Since water vapour is one of the products of the combustion of gas, it follows that liquid water will be formed if this vapour be allowed to condense. In the past it was customary for this to be the normal state of affairs, with the result that geysers and the like had to be provided with some suitable means of disposing of the condensed water. Modern practice tends towards the complete avoidance of the condensation of the water vapour, for the reasons given below.

Heat Evolved When Gas is Burnt. The heating effect of gas is the major consideration nowadays in all processes concerned with its utilization. Even with lighting it is the heating of the mantle and its consequent incandescence which determines the amount of light produced. It is, therefore, only proper that the law should require gas to be measured and sold by its thermal value. Gas undertakings are required to declare their calorific value and, once declared, to maintain it at that value within closely prescribed limits. The public is thus assured of always obtaining the correct heating value for its money and, what is more important, a national standard is established which enables the price of gas from place to place to be compared and also ready comparisons to be made with electricity and other fuels.

Calorific Value and the Therm. The declared calorific value of the gas supplied by an undertaking is expressed in British Thermal Units per cubic foot. Gas is sold by the therm, which is equivalent to 100,000 British Thermal Units and is a more convenient unit than the B.Th.U. Since gas is sold by the therm and is still measured by a volumetric method in the meter it is often desired to convert cu. ft. to therms and vice versa. The methods are as follows:

$$\text{Therms} = \frac{\text{Cu. ft.} \times \text{Declared calorific value}}{100{,}000}$$

$$\text{Cu. ft.} = \frac{\text{Therms} \times 100{,}000}{\text{Calorific value.}}$$

The declared calorific value of a gas is the total amount of heat obtained when one cubic foot of it is burned completely. It has been shown above that when this occurs water vapour is produced. If this water vapour is permitted to escape uncondensed it carries with it its latent heat (*which see*) of vaporization, and thus the heat realized is less than it would be if the water vapour were condensed into liquid water and the latent heat recovered. The former amount of heat is referred to as the net calorific value, while the full amount is more accurately described as the gross calorific value.

For practical considerations it is now usual to avoid condensation occurring in appliances. The sacrifice in heat obtained is so small that the effect on the thermal efficiency may be ignored. On the other hand, condensation decreases the life of an appliance, increases the maintenance service required, calls for additional installation work in order to effect disposal of the water and, if it is not properly disposed of, may cause inconvenience. Hence the majority of appliances are now designed in such a manner that condensation does not occur.

For further information *see* Gas Fitting; *also* Combustion; *and* Gas: (1).

B. GAS PRESSURE AND THERMAL EFFICIENCY

The two principal considerations in satisfactory gas utilization are the maintenance of the correct pressure and the assurance of perfect combustion of the gas when burnt.

Gas appliances today are designed to operate within critical limits of specified rates of gas consumption. For any given appliance the rate at which gas will be burnt depends upon the pressure available at that appliance, and if the appliance is to continue to operate uniformly it is imperative that the desirable pressure shall be maintained. The whole of a gas distribution system is designed to ensure these

constant pressure conditions at appliances.

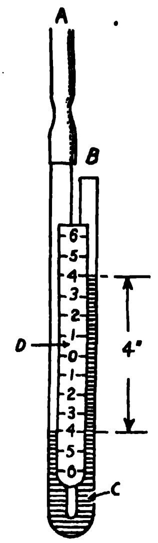
At the works the gas is stored in holders having either a floating lift or, in the latest waterless type, having a loaded piston. In either case the weight supported by the gas is the origin of the pressure in the distributing system, although in certain circumstances additional pressure is obtained by pumps. The determining factor in a gas distributing system is the variation in the loss of pressure (due to the resistance of the pipes, etc.) consequent upon variations in the demand for gas. At times of peak demand (such as during the cooking period) the velocity of gas through the mains and other parts of the system is high, the energy expended by the gas is great, and thus the loss of pressure is considerable.

Importance of Adequate Pipes. As far as is possible the pressure at the point of entry to consumer's premises is kept constant by automatic control at the gas works, and at various points automatic pressure regulators (or "governors") are installed in underground manholes in the streets. There remains, however, the problem of the varying loss of pressure which occurs between the main and the appliances in the consumer's premises. The internal carcass pipes should be such that there is no appreciable pressure loss when the installation is on full load—*i.e.* when all the appliances are in use. Thus at any given appliance the pressure will be the same whether that appliance alone is in use or every other appliance on the same service is in use—provided, of course, that the pressure in the street main is maintained constant.

How Gas Pressure is Measured. For all normal purposes gas is distributed at very low pressure, usually only a few inches of water column. Modern gas appliances require an operating pressure of 2 to 2½ in. water gauge, and this is satisfactorily obtained if the pressure in the mains is in the region of 4 in. gauge. This is only about 1 per cent. in excess of atmospheric pressure, which is 14·7 lb. per sq. in., and equals 407 in. water gauge absolute. Gas pressures are best measured with the simple U-tube gauge (Fig. 1). Apart from measuring the pressure loss along a pipe line or in a carcass it has many other uses, chief among which are testing carcasses and installations for soundness and adjusting appliances to correct rates.

Pressure Loss in Pipe Runs. From the foregoing it will be seen that the small initial pressure available in the service to any given premises does not permit of any undue loss of pressure of the gas in flowing through the system to the appliances. It is now common practice so to proportion the pipes in a carcass that the maximum pressure loss at the time of full load in the premises does not exceed ½ in. water gauge. This is made up as follows: along the service pipe, one-tenth; across the meter, two-tenths; and in the house pipes, two-tenths.

Maintenance of Constant Pressure. Although every possible precaution is taken both at the gas works and in the street mains to maintain constant pressure,



GAS. TOWN'S, UTILIZATION: Fig. 1. U-tube gauge. Limb A is attached to gas supply and limb B is open to atmosphere. The gas pressure is shown by the difference in water levels. In this case it registers a pressure of 4 in. water gauge. The scale is marked off in half-inch divisions, the reading being taken at either water level. (See Pressure Gauge.)

there are occasions when local pressure variations render some form of automatic control desirable. If the mains pressure fluctuates but the house pipes are of adequate bore, a constant pressure governor may be fitted at the meter to control the pressure to all the appliances in the premises. If the house pipes, however, are not sufficiently large for the load, irrespective of whether the mains pressure is uniform or fluctuating, it is necessary to install a separate governor to each individual appliance. It is now, in fact, becoming common practice to incorporate governors in practically all modern gas appliances so that they will give the maximum service no matter where they are used, or how much local conditions of supply may vary.

Governors incorporated in appliances may be either of two types—constant pressure or constant volume. The former automatically adjusts any variation of the pressure on its inlet to a constant pre-determined pressure at its outlet. If the burner orifices of the appliance are calibrated it is possible so to proportion their diameter, and the pressure set by

the governor, that a constant rate of gas consumption will result at any of the burners of the appliance. A diagrammatic cross section of a simple type of pressure governor is shown in Fig. 2. It consists of a cylindrical casting or stamping with inlet and outlet connexions. A flexible rubber, leather or silk diaphragm supports a valve above an annular seating through which the gas passes. The diaphragm is loaded by weights, so that a certain gas pressure is necessary to support it in equilibrium. Any fluctuation in the inlet pressure will inflate or deflate the diaphragm and cause the resistance offered by the valve to alter correspondingly to keep the outlet pressure constant.

The constant volume type of governor is suitable only for appliances having one burner, but has the advantage that it will deliver only a predetermined flow of gas to the appliance. It cannot be used on appliances, such as cookers, which may be required with one or several or all burners in use at any one time and must thus be used with a variety of rates of gas consumption.

Combustion Requirements. The importance of ensuring the satisfactory combustion of gas cannot be overemphasized. The modern gas appliance is so designed that, with the appliance by itself, perfect burning of the gas will obtain. In order that these conditions shall continue, when the appliance is installed in any given circumstances, it is necessary to observe a few simple precautions. Gas is possibly the easiest fuel to burn; its satisfactory combustion is simplicity itself to obtain, and no conditions other than these should be tolerated. *See* notes in pages 462–3.

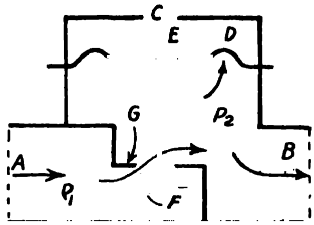
Thermal Efficiency. The thermal efficiency of an appliance is the ratio of the useful heat obtained to the amount of heat used in the gas burnt. If an appliance is intended to perform a given duty (such as a water heater delivering so many gallons per minute raised so many degrees Fahrenheit), it is possible to state this in British Thermal Units and, knowing the calorific value of the gas and the thermal efficiency of the appliance, to arrive at the number of cubic feet of gas which must be burnt per minute to give the required delivery of hot water at the desired temperature.

The gas rate (usually expressed in cubic feet per hour, or B.Th.U. per hour) is thus the all-important consideration, and is closely linked with pressure, combustion, condensation, and general satisfactory performance of appliances.

C. VENTILATION OF GAS APPLIANCES

The question is often asked as to why some gas appliances must be provided with flues while others are expressly recommended for use without flues. The question is not one of danger, provided the appliance is properly designed and correctly functioning, but of comfort to the occupants of the room in which the appliance is used; and is concerned with the ratio of the gas rate to the size of the apartment in which the gas is being burnt. It has already been shown, in the article Gas: (1), that the combustion of gas results in the production of heat and water vapour, and this in excess will naturally result in discomfort.

GAS. TOWN'S, UTILIZATION. Fig. 2. Diagrammatic cross section of simple constant-pressure gas governor: gas enters at A under inlet pressure P_1, passes between valve F and its seating G to outlet B; flexible diaphragm D is weighted at E to pressure equivalent to outlet pressure P_2; space above diaphragm is ventilated to atmosphere at C to allow free movement.



A special committee of the Royal College of Physicians recently investigated this problem and issued a comprehensive report in which it was emphasized that no harmful results could be produced by burning gas fluelessly; the committee made the following recommendations with regard to limiting conditions.

> The maximum desirable rate of gas consumption without a flue is 9 cu. ft. of 500 C.V. gas per hour per 1,000 cu. ft. of room capacity if used continuously in a room having up to 1½ air changes per hour. If the gas is to be burned intermittently—as is usually the case—the gas rate per 1,000 cu. ft. of room space may be increased to 18 cu. ft. per hour.

With gas-heating appliances it should be borne in mind that the provision of a flue has an advantage additional to that of providing heat, in that it also promotes ventilation; a flueless heater provides heat only.

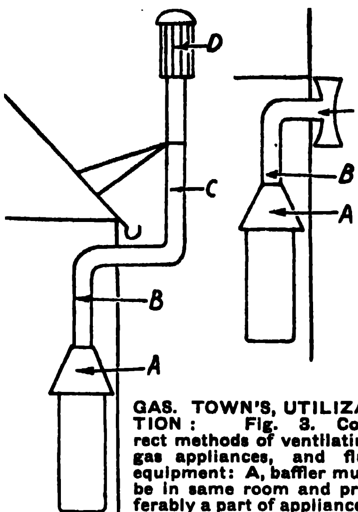
Principles of Ventilating Gas Equipment. Where gas appliances must be fitted with flue equipment—as is

necessary with high gas-rate water heaters in small bathrooms—it is of the utmost importance that the purpose of the parts should be understood and that they should be assembled and located correctly.

The addition of indifferent flue equipment to an otherwise satisfactory appliance may produce results far worse than could possibly obtain with the appliance burning flueless.

The general arrangement of the flue to a gas appliance is shown in Fig. 3. It will be seen that it consists essentially of four parts: primary flue, baffler, secondary flue, and terminal. With modern appliances requiring to be ventilated, the baffler is incorporated as an integral part of the appliance, and thus the primary flue is also part of the appliance. It is essential that the baffler shall be designed to suit the particular appliance for which it is intended; and the practice of using baffler for universal application has, except in certain rare and special circumstances, been discontinued. Bafflers and baffler testing are now covered by British Standard Specification and no baffler or draught diverter should be countenanced which does not conform to this.

The purpose of a baffler is not to prevent downblow—that is impossible—but to stop it reaching the combustion space by diverting it away from the burners into the room in which the appliance is working. It serves a further useful purpose in breaking the direct draught "pull" on the burners which, if excessive, would lower the thermal efficiency. On no account should a proper baffler be omitted from the flue to a gas appliance, and the baffler must always be fitted in the same room



GAS. TOWN'S, UTILIZATION : Fig. 3. Correct methods of ventilating gas appliances, and flue equipment: A, baffler must be in same room and preferably a part of appliance ; B, secondary flue; C, extension of B taken to exposed position well clear of eaves, etc. ; D, terminal, wind and blockage proof ; E, flush wall terminal if CD should be unsuitable.

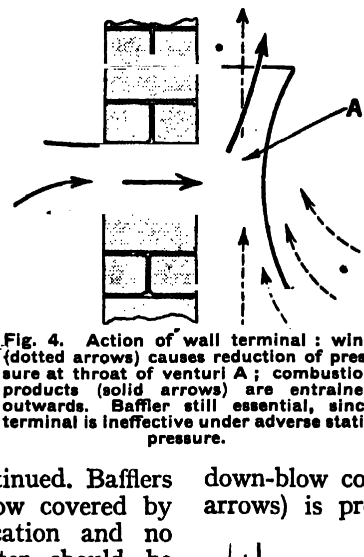


Fig. 4. Action of wall terminal : wind (dotted arrows) causes reduction of pressure at throat of venturi A ; combustion products (solid arrows) are entrained outwards. Baffler still essential, since terminal is ineffective under adverse static pressure.

as the appliance. This follows, of course, with up-to-date appliances, where the baffler is an integral part of the appliance. The purpose of a baffler will be seen quite clearly in Fig. 5.

Appliance (1) has a flue but no baffler, and is working under normal up-draught conditions. Excessive cold air (black arrows), drawn in at the base, causes a reduction in thermal efficiency. Installation (2) is the same as (1) but down-blow is occurring. Products of combustion, blown back on the burner, cause imperfect combustion and the gases are forced into the room from the base. Appliance (3) has a properly designed and installed baffler and is working under normal up-draught conditions. The opening in the baffler breaks the direct "pull" on the burner and entrains air which assists the ventilation of the room, at the same time preventing condensation in the flue by diluting the products of combustion. Installation (4), same as (3) but with abnormal down-blow conditions. The wind (black arrows) is prevented from reaching the

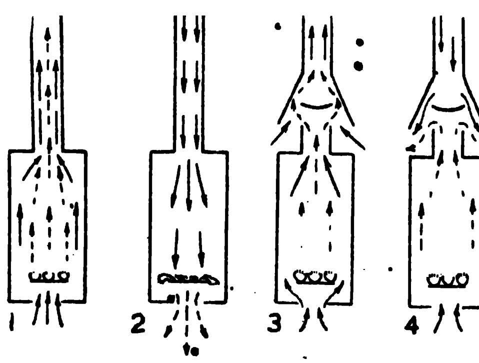


Fig. 5. Purpose of baffler in flue from gas appliance ; solid arrows show cold air from below and down-draught from above ; dotted arrows, products of combustion (see text for explanation).

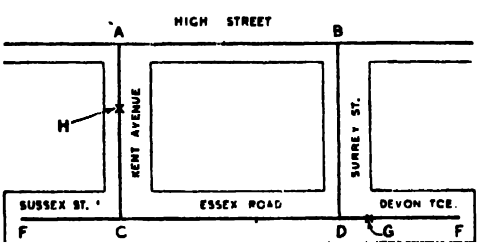
burners and is diverted, together with the products of complete combustion (dotted arrows) into the room from the opening at the baffler. Combustion remains perfect, only harmless products diluted with fresh air entering the room.

The function of the terminal is to prevent ingress of snow, rain or foreign matter, or of birds or small animals. It should be designed to minimize the incidence of down-draught and to take advantage of the air movement so produced to create an up-draught in the flue. No matter how effective the terminal, however, it is obligatory always to fit a proper baffler at the appliance, since no terminal can be guaranteed at all times and under all conditions to prevent down-draught.

D. GENERAL NOTES ON GAS MAINS

Distribution of Gas. Gas is distributed from the manufacturing station to the consumers' premises by a variety of methods according to local conditions and the size of the network of mains. As a general rule the low pressure arterial system is employed wherever possible. This consists of linking up all the mains and each of the works if there are more than one. The system has the advantage of equalizing district pressures and precludes any possibility of a failure, since in the unlikely event of a breakdown the gas is not shut off but flows in another direction. Fig. 6 shows a small part of a mains system, and indicates how a repair may be effected or a branch inserted at point H without interfering with the supply of gas to any of the consumers in the neighbourhood. For the cul-de-sac at G, a by-pass must be fitted before it can be cut out, otherwise all the users from G to F will be cut off.

Gas is sent out at high pressure in certain areas, particularly in rural dis-



GAS. TOWN'S, UTILIZATION: Fig. 6. Street plan showing gas mains linked up (A, B, C, D) so that gas can flow in alternative direction if necessary to bag off main for repairs or inserting branch; in culs-de-sac (CF, DF) part to be cut must be by-passed before commencing other work; at H gas can be obtained either way, at G from one way only.

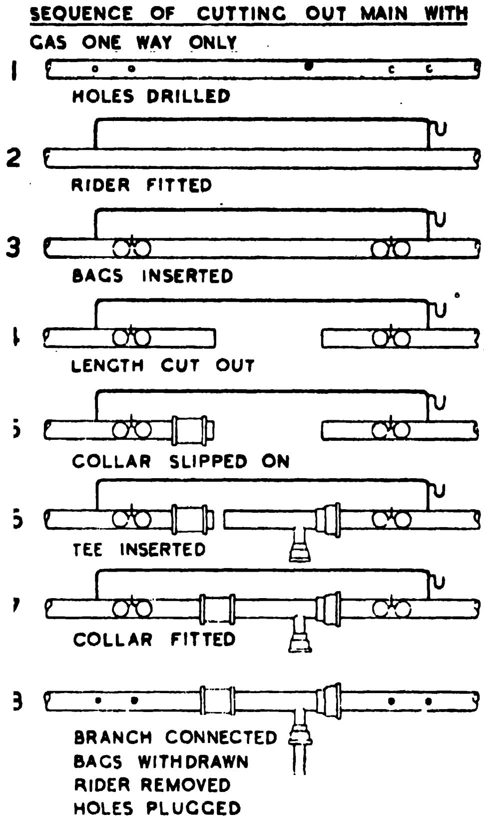


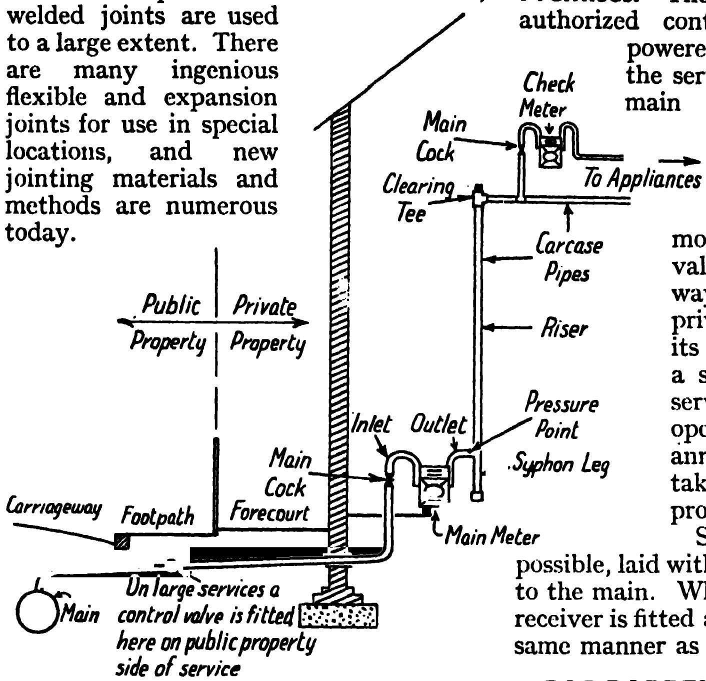
Fig. 7. Sequence of operations when gas main is cut to insert branch, gas being "one way" only, as in culs-de-sac of Fig. 6.

tricts when long-distance transmission is inevitable. This method permits the use of much smaller mains, and the high pressure is governed down either at each individual service pipe or to a particular locality by a district governor. In some cases high pressure feeder mains are superimposed on a low pressure system, in order to boost up an outlying part of it which has developed rapidly or to an extent not originally anticipated.

Materials Used for Gas Mains. Both cast-iron and steel are used for gas mains. Cast-iron pipes are to British Standard Specification, and are either vertically cast or spun. Steel requires adequate wrapping as a protection against external corrosion. Irrespective of other conditions—size, length, soil, etc.—steel is invariably used today if the internal pressure (*i.e.* the gas pressure) exceeds 5 lb. per sq. in. Service pipes between the main and the consumers' meters are of steam weight wrought iron or mild steel, and are either coated and wrapped to

prevent corrosion or are laid in wooden troughs and completely submerged in pitch.

Joints. The usual British Standard joints—open, half turned and bored, etc. —are used on main pipes; while service pipes are screwed with the British Standard Pipe Thread. In addition, welded joints are used to a large extent. There are many ingenious flexible and expansion joints for use in special locations, and new jointing materials and methods are numerous today.



GAS: TOWN'S. Fig. 8. Gas installation in a house: diagram showing typical method of entry of gas supply, with names of principal parts of installation; check meter at top used only if it is desired to meter separately a part of premises.

Valves. Although mains are controlled by valves at vulnerable points such as bridges, it is not the general practice to fit many valves on gas mains. The ease with which the gas can, if necessary, be shut off (by drilling the main and inserting a bladder or rubber bag and inflating it) obviates the necessity for valves. These in practice are seldom, if ever, used and call for a considerable amount of maintenance service if they are to be workable on the very infrequent occasions that they might be wanted.

Receivers. Gas mains are laid with a "fall," and receivers are fitted at the lowest points to collect condensate. Many gas undertakings are now de-hydrating their gas so that no water enters the mains or any part of the distributing system. It is still customary to insert receivers, as they form a safeguard against flooding from extraneous causes, such as the water from a broken water main entering a broken gas main. One form of receiver is so designed that it can be purposely flooded to act as a shut-off valve. The flooding is confined to the receiver and cannot enter the main pipes.

Service Pipes between Main and Premises. The gas undertaking or its authorized contractors are alone empowered to lay, alter or remove the service pipe between the gas main in the street and the meter in the premises. Where the service pipe is of an internal diameter of 2 in. or more, a suitable control valve is fitted in the highway on the main side of the private property line and its location indicated by a surface box cover. This service valve would be operated at least once per annum by the gas undertaking, to ensure its being in proper order and condition.

Service pipes are, wherever possible, laid with a fall from the premises to the main. Where this is not possible a receiver is fitted at the lowest point in the same manner as for the street mains.

GAS BARREL. Term used colloquially for wrought-iron and steel tube as employed for gas services and carcass pipes. Screwed pipes for domestic services are made in three weights—light, medium and heavy, correctly described as class A, B and C weight tubes respectively. The only difference between these tubes lies in the thickness of the strips of metal from which they are made (the strips are formed into tubular shape and the seam butt-welded). Thus, whatever the "weight" of the tube, the outside diameter is the same in each nominal bore size: the wall thickness varies from 8 S.W.G. for Class C weight of 1 in. nominal bore to 10 S.W.G. for Class B weight, and 12 S.W.G. for for Class A weight. (For a Table of standard dimensions *see* page 759.)

Steam weight is employed for all service pipes and for many carcass pipes. The I.G.E. Regulations require its exclusive use for services; and it is also employed for all parts of interior carcass which have to be bent in the forge. *See* Pipes: (4); *also* Gas Fitting; Pipework.

GAS FIRES, AIR HEATERS AND RADIATORS: TYPES AND FIXING

By J. Murray Grammer, A.M.Inst.Gas E., A.M.I.H.V.E.

Heating by Gas is the subject of a later article, under its own heading. The present contribution deals with the main types of heating appliance in which gas is the fuel. Gas fires of the various types are described, with the appropriate data, and other sections deal with flueless heaters. See Gas Fitting; Heating: (5).

The general term "gas fire" covers a gas heating appliance which gives out some of the heat emanating from it as radiant heat with visible glow and light as distinct from a convector heater, a panel heater, an air heater or a background heater.

The gas fire produces warmth in a manner similar to that of a coal fire, nearly all the heat being emitted as radiant heat. Radiant heat (*see* Heat) travels in rays, and a person can experience a sensation of warmth if sitting or standing in the path of the rays from the fire, even though the surrounding air may be cool. The gas fire, too, has a cheery appearance.

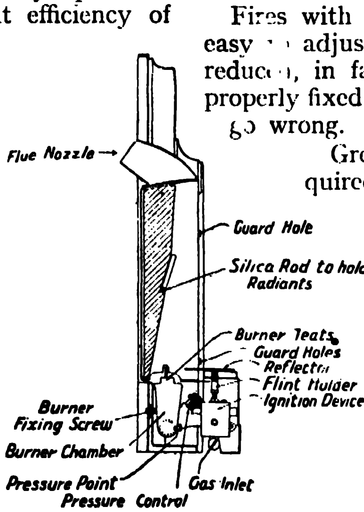
A. TYPES OF GAS FIRE

Gas fires can be divided into the types with flues, having gas rates between 20 and 50 cu. ft. per hour, and the flueless types with maximum gas rates of 15 or 18 cu. ft. per hour. Those of the first group have radiant efficiencies of over 50 per cent., and are fixed rigidly before fireplaces or to specially prepared flues, while the second group are generally portable heaters and have a radiant efficiency of some 25 per cent., even though the overall thermal efficiency is 90 per cent.

Flued Gas Fires. The flued fires, which are the gas fires proper, can be classified according to their particular methods of fixing. Makers alter their designs by varying the appearance and the setting of their radiants. Some fires have tubular radiants, others almost square radiants; and one popular make has wide flat-fronted radiants each unit of which emits an amount of heat equal to a 1 kilo-watt electric heating element. In some fires the radiants are set on an inclined brick; others on a flat, vertical brick, a convex brick, or on a concave brick. But in all cases the radiant efficiencies vary little, although the heat distributions and the appearances are affected. Development in gas fire design is directed to burning more gas per radiant at the same high efficiency. The effect is to produce a greater heat output per radiant and to allow a compact 3-unit fire to do the same work as the bulkier 4-unit type. Flued fires also differ in methods of automatic ignition.

Since 1945 "non-aerated" or "neat" jets have been introduced by several makers of radiant gas fires. Thermal efficiencies remain the same although heating up is a little slower. These jets have almost completely overcome one disadvantage of the aerated burner; that is, the blocking of the burner teats by "fluff" which collected under the fender and was sucked, with the primary air for combustion, through the air inlet ports.

Fires with these jet burners are very easy to adjust, and thus maintenance is reduced, in fact once the fire has been properly fixed there is virtually nothing to go wrong.



GAS FIRES, AIR HEATERS. Fig. 1. Flued fire, independent hearth type, having high gas rate and heat output for width; can be turned down to half rate without serious efficiency loss (compare Figs. 2 and 3).

Great care in fixing is required, however, to see that the flames from the jets neither come into contact with each other or touch parts of the firebrick and radiants. "Sooting up" would soon occur, so any faults in the setting of burners or in the luting of the firebrick should be corrected by the installation fitter.

Figs. 1, 2 and 3 show various constructions of flued fires. The independent or

semi-independent hearth fires are the most popular, since there are no protruding nozzles and firebricks, and they can be placed in front of nearly every type of grate opening without fouling the firebars. To improve the finished appearance of the installation, however, the grate opening should be shut in by a surround. This also prevents dirt falling down and out into the room.

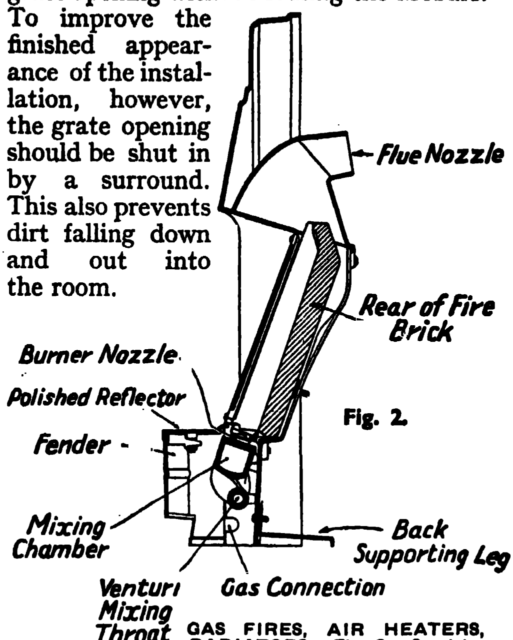


Fig. 2.

GAS FIRES, AIR HEATERS, RADIATORS. Fig. 2. Semi-independent hearth fire with inclined firebrick and radiants; can normally be treated as independent, but incline causes projection around flue nozzle. Fig. 3. Inset hearth fire suitable for existing fireplace; ventilation depends on canopy of grate into which it is fitted.

Other types of flued fires are the independent convector fires, which stand forward in front of a surround and which are so designed as to allow air to flow in at the base, over the heated surfaces, out through slots in the top of the fire, and into the room again. Another semi-independent fire is designed with a low front casting so that it is suitable for fixing in front of "Devon" grates.

Inset Fire. Inset fires depend upon sufficient space being left in the grate opening to take the whole of the firebrick and burner portion of the fire. When fixed to an opening cut in a surround, a complete front casting is employed; but when stood right into an existing fireplace the strength of the fire depends upon its side pillars alone. This latter fixing provides a very neat job, but care must be taken to seal the space at the top between the back of the firebrick and the face of the original fireplace with Purimachos or some other fireclay material. This is to prevent a draught up the back of the fire upsetting the performance of the burners.

Panel Fire. This type requires a little more work in fixing than the others; existing openings may be bricked up to provide an aperture just sufficient to take the fire. The panel fire, however, produces the neatest and best-looking job.

Automatic Ignition. Probably the most popular method of ignition is by means of a serrated steel wheel working against a stationary, spring-loaded flint.

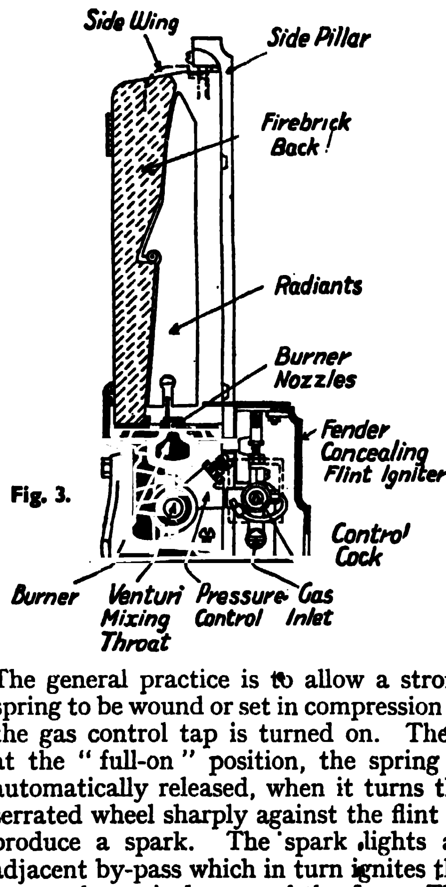


Fig. 3.

The general practice is to allow a strong spring to be wound or set in compression as the gas control tap is turned on. Then, at the "full-on" position, the spring is automatically released, when it turns the serrated wheel sharply against the flint to produce a spark. The spark lights an adjacent by-pass which in turn ignites the gas at the main burner of the fire. The flint igniters are robust, and mechanical defects do not occur very often. The only maintenance necessary is the renewal of the flint, once every year or eighteen months.

The two other methods of automatic ignition employ a platinum catalyst to ignite the gas. The earlier type requires a small electric dry battery to provide a current to warm the platinum wire and so increase the speed of the reaction between the hydrogen in the gas and the oxygen in the air (the hot catalyst method).

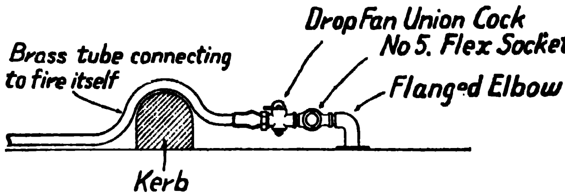
The second type (cold catalyst method) employs the finely divided form of platinum known as platinum black, in addition to the platinum wire. Even at normal temperatures oxygen and hydrogen, if in the right proportions, begin to burn on the platinum black. The heat from this initial combustion then warms the platinum wire, and the ignition of a larger mixture takes place and flashes to the main burner.

The "cold catalyst" is preferable for gas-fire burners, and a correctly set fire will light up within three seconds of the gas being turned on. But a damp catalyst, a poorly adjusted burner, or a badly fitted fire (*e.g.* no luting to prevent draughts up the back of the fire-brick) will cause delays in ignition and sometimes complete failure. Care in fixing and adjustment of cold catalyst fires is therefore essential. The electro-catalytic igniter or "hot catalyst" serves very well, but defects arise through faulty electrical contacts, short circuits and over-gassing of the by-pass jets. All three types are on the market.

B. FIXING GAS FIRES

The standard method of fixing a gas fire is to stand it before the existing grate (preferably filled in with a surround) and to make the gas connexion to it in brass tubing. The gas supply generally passes through the floor on the right-hand side of the fireplace with a ½-in. stub nipple, and to this a brass flange elbow is screwed and then fastened to the floor. To the horizontal male thread of the flange elbow is screwed a brass union cock. The brass tube to the fire is then shaped and screwed into the fire, and connected to the cock by means of the union. For maintenance purposes, etc., the ease with which the union and fire can be disconnected is a great advantage.

Where a coloured or decorated fire is installed, chromium-plated tubing and fittings should be used. The best finished jobs are obtained by chromium-plating the brasswork after it has been set and screwed together to its correct shape. In any circumstances it is best for the gas supply itself to be entirely out of sight, and in many new houses concealed fire points are left in the centre at the bottom of the grate. This method often does away with the union cock as an additional control to the cock on the fire itself, but in small houses and flats, where it is easy for the gas to be turned off at the meter before maintenance work or alterations take place, this is not a serious matter. If an extra control cock is deemed necessary, then a union cock of the type with double unions (to enable easy removal for greasing, etc.) should be fitted under the floorboards, and a floorplate fitted flush to the boards should be inserted over it.



GAS FIRES, AIR HEATERS, RADIATORS. Fig. 4. Method of inserting flex socket on gas fire supply to provide plug-in point independent of fire. (*See also* under Plug-and-Socket.)

Plug-in Points. Although several types of gas fire can be fitted with pedestal boiling burners or even concealable boiling burners, it is sometimes desirable to provide a plug-in point on the fire supply itself so that a ring or other portable appliance can be used irrespective of whether the cock to the fire is turned on or not. Fig. 4 shows how a socket for a plug in connector can be inserted on the supply: the flex socket can pass gas whether the union cock to the gas fire is turned on or off. The union cock is of the safety drop fan type, which cannot be turned on until the fan of the cock is lifted from its horizontal position to a vertical position. (*See* Plug-and-Socket.)

Surrounds. Some years ago if a surround were fixed at all it would consist only of a comparatively thin sheet of iron screwed directly on to the casting of the fireplace itself (many of the older grates are of cast-iron), or else on to vertical and horizontal battens wedged between the hearth and mantelshelf and the jambs, respectively. The sheet iron did not pre-

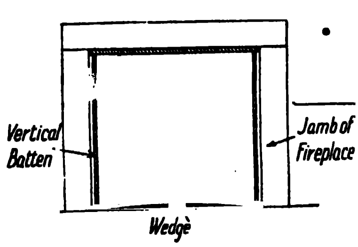
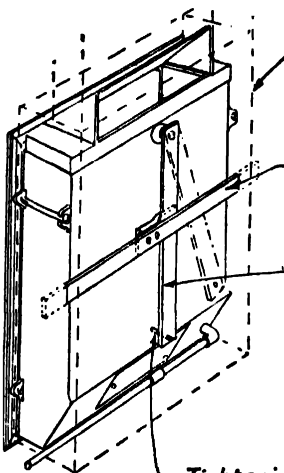


Fig. 5. Fire surround to cover fireplace opening: surround screwed to wedged-up wood battens.

sent a pleasing appearance, especially as the fire and surround were generally painted black, and in time rust spots would show through on the sheet iron. The latter was also an unpleasant material with which to work, and if fixed too rigidly would buckle during temperature changes caused by the lighting and extinguishing of the fire.

The next common material to be employed for cheap surrounds was the asbestos-cement sheet. This is still used



GAS FIRES AIR HEATERS, RADIATORS. Fig. 6. Rear of panel fire let into specially constructed opening, showing rigid vertical bar and cross member built into brick sides.

extensively today, and like the sheet iron is shaped and then screwed on to wooden battens. Like sheet iron, it has the advantage of being incombustible. Care must be taken in working it for fear of cracking or disfigurement. If a coloured finish is to be given to the surround, a good " sealer " coat should go on before applying the undercoat and the final finish, otherwise a blotched effect will be produced.

The best surface for colouring is that of the panel boards and other made-up compressed sheetings, which provide a fine glossy surface for painting. Panel boards can be cut very easily to size of the grate opening. They are screwed to battens as are the other materials, but require less support. The main objection to them is that they are not incombustible.

Metallic finishes on fires with surrounds to match provide another arrangement. The method of fitting the surrounds is to set up five pieces of sheet metal in the same finish as the fire, causing them to overlap, the centre one being fitted above the flue nozzle of the fire. The outer edges of the five pieces are screwed on to wood battens, but where the overlapping takes place inside the area covered by the fire casting, the pieces are bolted together for rigidity.

Tiled surrounds which are normally installed by builders are generally stocked already made up in standard sizes, but more elaborate types in marble, glass, etc., would be made up to order.

Panel fires demand openings of fixed and predetermined dimensions, very often plaques are supplied to be let into the face of the wall or chimney breast, providing an exact opening and a good support. The general method of arranging the main support is by means of a rigid cross member let into either side of the brick opening. Fig. 6 shows one such application of this method.

C. GAS FLUELESS HEATERS

Besides the flueless gas fires (mostly of the portable type) already mentioned, there are three further types of flueless heaters in common use: air heaters or convectors, gas radiators with some radiant heat, and radiant panel heaters.

Convectors. The convector type was the first to be used extensively, and normally consists of a cast-iron body divided into two sections. Gas is burned freely in a comparatively large combustion space at the base, entraining air which is warmed and travels up one half of the appliance and down the other to an outlet at the base or side of the heater. The heater is designed to pass warm air out into the room and also to encourage outside air to flow over its heated surfaces, thereby setting up warm convection currents in the room itself. The surface temperatures on a good type of convector should compare with that of a hot water radiator.

Normal gas convectors are designed for use in flueless rooms, corridors, shops, etc., but the number of appliances and gas rates (gas rates range up to about 20 cu. ft. per hour, 500 C.V. gas) should be determined by the ordinary heat loss calculations. An overall efficiency of 90 per cent. may be assumed.

Free-standing convectors are generally mounted on asbestos-cement slabs, and if in public buildings are made rigid by distance pieces and brackets between the tops of the heaters and the walls.

Special wall fixing convectors known as " Background Heaters " can be fitted with integral fixing pieces to the walls of the room remote from the fireplace, and in the smaller sizes can fit into the usual radiator position (*i.e.* beneath the windows).

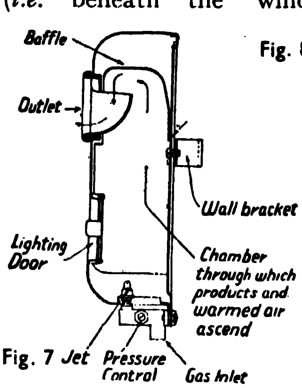


Fig. 7

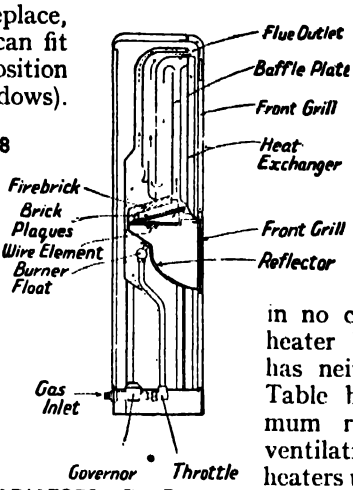


Fig. 8

GAS FIRES, AIR HEATERS, RADIATORS. Fig. 7. Small " Background Heater," convector to be fixed on wall as supplement to other heating ; approved gas rate, 4 cu. ft. per hr. ; heating output approximately equal to a 6-loop hot-water radiator. Fig. 8. Flueless free-standing radiator giving over 25 per cent. of its heat as radiant heat ; approved gas rate 18 cu. ft. per hr.

Background heaters (Fig. 7 shows a small type) are only intended to warm up the air and the remoter parts to such a temperature that the addition of heat from a solid-fuel or radiant fire would soon bring up the room to full comfort conditions.

Gas rates, as low as 4 and 6 cu. ft. per hour per heater, require the simplest of burners and controls. The supply can be run in $\frac{3}{16}$ in. copper pipe along the skirting board, so that the heaters can be installed with a minimum of disturbance.

Gas Radiators. The old-fashioned type of "radiator" has been superseded by a type of air heater. (*See also under* Radiator, Gas-heated.) Modern gas radiators with some radiant emission (Fig. 8 is a type which emits more than 25 per cent. of its heat as radiant heat) provide a more cheerful appearance than the air heaters. The radiant elements consist either of a nichrome wire element or an ordinary fireclay radiant, but gas rates are generally limited to about 20 cu. ft. per hour maximum.

The radiators, generally free-standing, are fixed like the convector heaters and are for use in shops, offices and flueless rooms in domestic premises.

When fixing flueless gas appliances in habitable rooms there are three factors which should be borne in mind :

(1) The heater must satisfy the combustion requirements as laid down by the B.S.I.

(2) The gas rate must be related to the room size.

(3) The room ventilation must be adequate.

Point 3 means firstly that in no circumstances must a flueless heater be fitted in a room which has neither air brick nor flue. The Table below summarizes the minimum requirements of room sizes, ventilation and gas rates for flueless heaters using 500 C.V. gas.

Radiant Panel Heaters. Designed to emit as much heat as possible by radiation, although the source is not visible. They must not be confused with hot water or steam panels which operate at much lower temperatures and require even larger surfaces.

Concentrated high temperature radiation is avoided by dispensing with the elements and radiants, and having instead large black matt surface of much lower average temperature.

This provides a more even distribution of heat although the source is not visible. Soon after lighting up, persons

VENTILATION AND GAS RATES

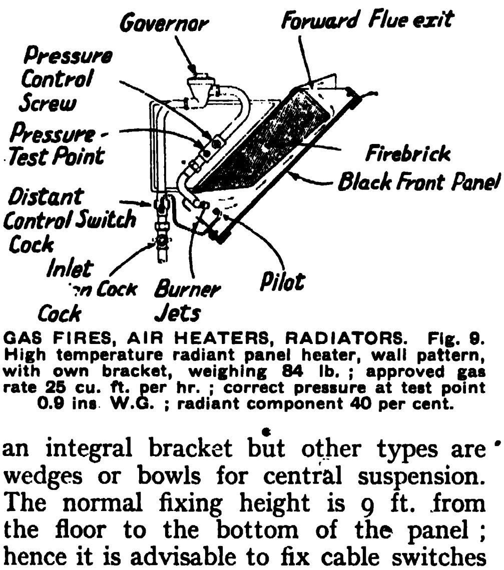
Type of Room	Minimum Size of Air Brick* (Free area)		Max. Gas Rate Permissible (Per 1,000 cu. ft. room space)
	Brick to Outside air, no flue	Brick to internal landing, no flue	
Not of abnormally tight construction	10 sq. in.	20 sq. in.	5 cu. ft./hr.
Ditto.	20 "	40 "	10 "
Tight construction	20 "	40 "	5 "
Any type	Room with normal Flue Min. flue 20 sq. in. free area		10 cu. ft./hr.

*Air bricks should be of such a design, e.g. louvred, that they cannot readily be blocked up by the occupant.

in the room feel the comfort effect of radiant heat even though the actual air temperature may be comparatively low.

The heat transfer is generally effected by passing the flames and hot products between an inclined firebrick and the black-faced front panel. This means that the ray of heat becomes a downward one (say at 45 deg.). Radiant panels have the advantage of wall fixing or suspension fixing, thereby taking up no floor space, and are popular in such places as schools, factories, churches, halls, restaurants, shops, etc. As the heaters are designed on the whole for these large premises, gas rates go up to 25 cu. ft. per hour, the radiant efficiency being 40 per cent.

Fig. 9 shows a wall-fixing type with



GAS FIRES, AIR HEATERS, RADIATORS. Fig. 9. High temperature radiant panel heater, wall pattern, with own bracket, weighing 84 lb. ; approved gas rate 25 cu. ft. per hr. ; correct pressure at test point 0.9 ins. W.G. ; radiant component 40 per cent.

an integral bracket but other types are wedges or bowls for central suspension. The normal fixing height is 9 ft. from the floor to the bottom of the panel ; hence it is advisable to fix cable switches of the Newbridge type for easy control.

GAS FITTER. The work of the gas fitter may be included in Specifications and Bills of Quantities as a provisional sum, although the Quantities are sometimes worked out. Information to be included in a typical Specification is given below.

General. The contractor required to carry out all work described, leaving the system in complete working order, and to be responsible for maintenance for six months. The contractor to make all necessary arrangements for the supply and for the necessary connexions to mains.

Mains Connexions and Meters. Method of tapping mains described—junctions, size of pipe—all to be done to the satisfaction of the Gas Board. A gas-control cock to be installed in position indicated. Type of meter or meters, positions, and fixing must be given.

Piping. Describe material and finish of pipes and all joints, methods of making joints, lengths of pipe and diameter of each length, use of bends, elbows, tees, angles, crosses, nipples, brackets, couplers, caps, plugs, wall hooks, clips, bends, etc. No item to be omitted. Layout of pipe with points and cocks shown on plans.

Siphon Box, Governors, Control-Cocks, By-pass. Each to be provided by contractor and fixed where and as directed.

Fittings. All fittings to be provided and fixed by the contractor, must be fully described and their fixing detailed.

Painting. All pipes and fittings required to be free of rust. Kind of paint and number of coats to be specified.

Testing. All parts of the system to be thoroughly tested by methods specified, and all work to be to the satisfaction of the inspector of the Gas Board.

Internal Installation and Making Good. Instructions must be given under Carpenter for Internal Installation, and under Carpenter, Bricklayer cutting away, Plasterer for making good.

B.S. and Codes of Practice. The following B.S. and Codes of Practice Nos. 331, 332 and sub-Codes deal with gas flue pipes and fittings, plug and socket connexions for portable appliances, pipes and fittings, copper tubing and tubulars, meter and gas appliance installations : Nos. 567, 715, 143, 617, 1043, 570, 602, 659, 864, 1401-3, 1387, 1396 (*see* Supplement, Vol. 3).

Fire Precaution. No pipes for gas to be used as an electric earth.

Lighting. For gas lighting, layout is shown on plan and method of switch control indicated ; details are given of all materials used, positions of lights and switches, and all connexions. For high-pressure gas fittings and lamps special mains and branches must be shown on plan if supply comes from Gas Board, or description be given of high-pressure plant to be installed.

Heating and Hot Water Supply. Full description of apparatus and layout of gas pipe is necessary. Built-in flues specified under other trades, but flue connexions, runs, and vents given here.

Cooking, etc. Provision for installation of cookers and any special apparatus, as in a laboratory, specified.

GAS FITTING: OUTLINE OF PRINCIPLES & METHODS

By R. N. LeFevre, M.Inst.Gas E., A.M.I.Mech.E.

Though detailed information on gas fitting would lie outside the scope of this work, it is desirable to include notes on the basic principles and methods : the following contribution offers such notes with special application to the work of the plumber and heating engineer. See Gas ; Gas Fires ; Heating.

The great developments which have been made in the design of gas appliances in recent years, coupled with the increased applications of gas both for domestic and industrial purposes, have resulted in a complete change in the technique of gas-fitting practice. In addition to possessing a complete knowledge of pipework and modern installation practice, those concerned with the fixing and maintenance service of gas appliances must possess a thorough understanding of the basic principles of gas utilization in order to ensure that appliances will be correctly adjusted and will continue to function satisfactorily.

Methods and materials used in gas fitting work vary from place to place, according to local conditions, but the following notes give a general survey of what is generally accepted as the best practice throughout the country. The British Gas Industry has recently standardized this branch of its activities, and full details of the correct practice regarding the installation of gas appliances and pipes are laid down in the British Standard Codes of Practice for Building, Nos. 331 and 332 and sub-Codes, and also the "Post-War Building Studies" No. 6, Gas Installations. The last-named, a publication of the Ministry of Works, 1944, was the Report of the Gas Installations Committee convened in 1942 by the Institution of Gas Engineers. It covers Service Pipes, Internal Installations (Pipes, Meters, Appliances) and in appendices, brief specifications of 23 appliances for one-family dwellings and "bottled" gas installations.

Where applicable, references to these recommendations are included in the following notes.

Local considerations of gas supply and distribution may require local by-laws and regulations, about which full details will be furnished by the Gas Board on demand. In addition, the statutory regulations of the local authority often embrace certain requirements with regard to gas installations and equipment—as, for example, in the Administrative County of London, where the provisions of the London Building Act, 1936, with regard to fixing gas appliances must be closely observed.

Fixing of Meters. Meters must be fitted plumb and dead level. The small types are usually securely connected by means of lead inlet and outlet pipes and brass unions. Large meters are best connected direct in iron or steel tubing. All meters, whether primary (*i.e.* measuring all the gas used on the premises) or secondary (*i.e.* check meters recording the gas used in a flat or other separate part of the premises) must be provided with a separate gas control cock.

The control cock should always be in an accessible position, and located on the service pipe as close as possible to the inlet connexion to the meter. The control cock should be fitted so that no part of it is less than ⅛ in. clear of the wall or any other obstruction. If the cock has a detachable key, it should be securely fixed to the spindle or plug by means of a grub screw or split pin, so that the key is available for use when required.

By-passing Gas Meters. Where the undertaking decrees, it may be necessary to provide the meter with a by-pass to enable gas to pass direct to the appliances without registration in the event of the meter stopping. This practice is usual on large meters supplying gas for central heating or for industrial purposes, and on all meters to such premises as hospitals. By-passes incorporate inlet, outlet and by-pass valves, the latter being secured in the "off" position by a locking device which is sealed by the Gas Board. In the event of emergency the consumer may break the seal and open the by-pass valve provided he notifies the undertaking that he has done so. An estimated consumption is readily obtained for the period during which the meter has been on by-pass.

Pressure Points on Meters. Most undertakings now insist upon the inclusion

of a plugged point, teat cock, or special pressure nipple on the outlet of all meters. The point permits of the ready attachment of a pressure gauge for testing purposes when required.

Where the meter concerned is used for registering gas in order to arrive at the basis of charge for the gas used, no work may be done without the authority of the Gas Board, which must also be permitted to supervise the work and approve the position, size and method of fixing and connecting such a meter.

Position of Meters. Primary meters should be fitted so as to be as close to the main as possible but within the external wall of the main building of the premises. In certain cases, however, it may be preferable to house the meter in a specially constructed meter house or other suitable accommodation for the location and suitable protection of the Board's property. This is frequently done in factories and similar buildings, where fitting the meter in a special housing near the private property line obviates having an unduly long run of service pipe on the inlet side of the meter. The outlet pipe may then be altered as desired by the consumer without reference to the Board.

Meters must be so fixed that neither they nor any of the connecting pipes shall be in any danger of coming into contact under any circumstances with any electrical conduits, electrical apparatus or metallic conductor. The Regulations of The Institution of Electrical Engineers also contain clauses referring to the proximity of electrical conduits and fittings to gas pipes and fittings. Where adequate air space is not available some satisfactory form of insulation must be provided.

Meters should not be fixed in such locations as will subject them to heating or wide extremes of temperature, since their registration will be affected and their lives shortened by either extreme heat or extreme cold. Where a meter has to be fitted at floor level it must be raised on blocks or battens clear of floor and be adequately protected against damage.

In the Codes of Practice No. 331-102 and Post-War Building Studies No. 6 the following locations for gas meters are specifically prohibited :

(*a*) Immediately above any heating or cooking appliance.
(*b*) In the open.
(*c*) Under draining boards, or display slabs in butchers' shops, fishmongers' shops and similar establishments.
(*d*) Against damp walls.
(*e*) In any position in which the meter is likely to suffer damage or be exposed to adverse conditions likely to affect its accuracy or safety.

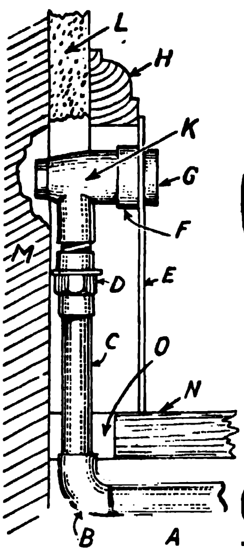
Internal Installation Pipes. Although compo pipe is still in use in many parts of Britain and possesses many advantages, it is usual to instal in buildings either wrought-iron or mild steel pipe. There is now a tendency to use copper pipe (British Standard Light Gauge) for the purpose, and many gas undertakings favour its adoption exclusively. Ferrous pipe and fittings for use with gas must be tested by the manufacturers to an internal pressure of 100 lb. per sq. in. while submerged in water ; and non-ferrous pipe and fittings must withstand a pressure of 100 in. water column (approximately 4 lb. per sq. in.) while similarly submerged.

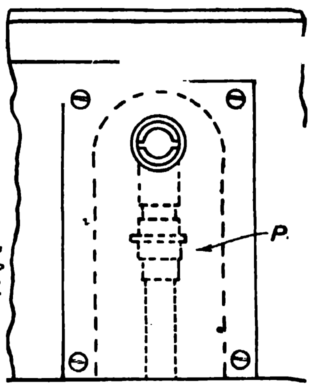
Joints. The threads of all pipes and fittings are screwed British Standard Pipe Thread and must be gas tight when made with a suitable jointing compound. If taper-taper threads are used, no hemp or other packing is necessary but is, in fact, a preventive to the making of a sound joint.

For copper pipe either capillary soldered or compression joints may be used. (*See* Pipe : (4).)

Size of Internal Installation Pipes. If satisfactory service is to be obtained from gas appliances coupled with economy in first costs of installation, it is imperative to select the correct size of pipe for each particular purpose. The reader should refer to the article on Estimating for Gas Fitting, where a table of sizes is given (page 368). Since the gas rate for any given appliance is known, it is a simple matter, with the aid of the table, to ascertain the size of pipe suitable for the length of the run to the appliance. Pipes must be sufficiently large to carry the anticipated load with a loss of pressure not exceeding one- or two-tenths of an inch water gauge. On the other hand, there is nothing to be gained by fitting pipes larger than necessary, as the cost of installation will be inflated and other work—cutting away, making good, etc. — increased proportionately. For similar reasons the size of meter also should be very carefully chosen.

Testing for Soundness. After completion the internal installation must be perfectly sound when tested with air under pressure. Testing is carried out by sealing all points except one to which is attached a tee-piece carrying a cock at one outlet and a water gauge at the other. Air is then pumped into the installation and the cock closed. After





GAS FITTING. Fig. 1. Flush plug-in connector in skirting board for portable gas appliance (vertical cross-section and front elevation). Hole P is cut in skirting board H and hole O in floor board N ; plaster L and brickwork M are cut away slightly ; gas supply A connected to plug-in socket K via elbow B, short tubing C and union D ; metal plate E covers P, is held to socket by screwed milled rings F and G, and secured to skirting by wood screws.

allowing 5 min. for adjustment of temperature, the pressure in the internal installation must remain constant for a period of at least a further five minutes. The usual test pressure in 6-in. water gauge, but individual engineers may require a higher test pressure and/or a longer time for test.

Portable Appliances. In recent years there has been a marked increase in the popularity of portable gas appliances (heaters, irons, pokers for igniting solid fuel fires, and boilers, wash-boilers, etc.) and much attention has been given to providing safe and effective connexion.

Metal nose or teat cocks and similar fittings to which rubber push-on connexions can be attached should not be used unless incorporated with a suitable safety device. The correct method is to fit a control tap of the bayonet type complying with British Standard Specification No. 570. There are five types of this fitting, each of which is suitable for a particular method of fixing ; between them they cover all possible arrangements required. The fitting takes the form of a socket attached to the rigid pipe and securely attached to the wall, skirting board or floor in the same manner as an electric plug-point. A plug is attached to the end of the flexible tubing, and acts as a key in that it is impossible to obtain gas at the socket unless the plug is inserted and turned.

All flexible tubing used for gas should conform to British Standard Specification No. 669. It should be provided with both ends screwed so that the proper connexion may be made both to the portable appliance and the plug.

Fig. 1 shows details of a plug-in connector for use as a flush fitting to skirting boards. The other types are interchangeable with this, but are for surface fixing.

Connexions to Appliances. Gas connexions should, where possible, be concealed. This is a simple matter in new premises if the runs are carefully planned and the location of the appliances determined beforehand; and if those responsible for the gas fitting work in collaboration with the other trades concerned. A good example of this cooperation is afforded by the neat fitting of a panel gas fire which can result if the fitter, bricklayer and plasterer work together on the job. The fitter runs his supply in behind the fire opening before the cradle is filled in. The bricklayer builds the fire opening to the dimensions required for the fire. The fitter fits his fire and surround, and finally the hearth, if any, is filled in and the plasterer finishes off around the plaque. (Fig. 2.)

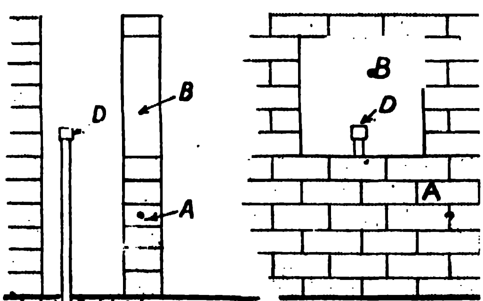


Fig. 2. Typical panel gas fire installation, showing method of concealing gas supply. Brickwork A is built up, leaving an opening B to the dimensions of the frame of the fire. Gas supply is run in ½-in. tubing, slipped through a sleeve of 1-in. pipe under hearth, and taken up to D. Thus supply pipe can be withdrawn if necessary. Gas fire is eventually fitted to the frame in brickwork and connected to supply pipe through a hole in the back of fire.

Provision of Flues. It has already been shown that the need for flues is determined by the gas consumption and period of use of any particular appliance. With space heating appliances it must be remembered that the normal type of gas fire is designed to promote ventilation in the room in which it is fitted, and must therefore invariably be fitted with a flue. For water heating appliances the following rules should be adhered to if it is desired to avoid the production of uncomfortable conditions in the room. Flues are necessary with:

1. All bath heaters of the rapid, instantaneous type.
2. Storage heaters rated higher than 15,000 B.Th.U. per hour.
3. Central heating units and boilers.
4. Wash-boilers, washing machines and similar appliances rated higher than 20,000 B.Th.U. per hour.
5. Any appliance fitted in a bathroom for heating water for a bath which has burners generating more than 500 B.Th.U. per hour per 35 cu. ft. of room space. In addition it is necessary in such cases to provide additional ventilation to the outside of the room by means of a shaft or aperture having an unobstructed sectional area of not less than 15 sq. in.

Size of Flues. If a flue is intended solely for a gas appliance, it is necessary to dimension it only to the actual ventilating requirements, since no soot will be formed. The following rules may be taken as a safe guide to the sizes of gas flues of all types:

1. On gas appliances, the cross sectional area of the flue should not be less than that of the flue spigot of the appliance.
2. With gas fires intended to ventilate the room, the inlet area of the flue should not be less than 20 sq. in.
3. The minimum flue sizes for gas fires are 20 sq. in. for rooms up to 1,000 cu. ft., 30 sq. in. for 1,000–1,500 cu. ft., 40 sq. in. for 1,500–2,500 cu. ft., and 50 sq. in. for 2,500–3,500 cu. ft. and the minimum dimension of any cross section should not be less than 2½ in.
4. No flue should be less than 2 in. minimum dimension in a horizontal section.

GASKET. A type of packing used on flange joints. The gasket is inserted between the flanges, and they are then drawn together by means of a number of bolts. The gasket may be of various materials, depending on the liquid or gas the pipe is required to carry. The most common are rubber, asbestos, and metallic lead. For high pressure, corrugated metal joints made of brass are most satisfactory. When fixing gaskets, both sides should be smeared with red lead or other jointing compound, the faces of the flanges should be painted, and the joint screwed up. Metallic lead should be used only when the flanges have ground faces. *See* Joint.

GASKIN (or Yarn) A type of soft rope made of hemp, loosely twisted together so that it may be rammed down solid into a socket of a pipe if required, or easily unravelled to make joints in screwed pipe. It may be obtained in two kinds: the ordinary plain yarn, or tarred yarn. The latter is prepared by steeping in a solution of Russian tar until it is saturated, and then allowing to dry. Yarn is used for a variety of purposes by plumbers. It is placed at the bottom of soil pipe sockets to prevent the molten lead running in the pipe; or at the joint between the earthenware drain and the soil pipe, to prevent the cement running into the pipe. Unravelled hemp is wrapped round the thread on wrought-iron tubes before the jointing compound is applied. *See* Joint: (2).

GAS POKER. A specially adapted bunsen burner used for lighting fires. It consists essentially of the injector, surrounded by a wooden handle, and the blade. The latter is a round or somewhat flattened tube, pointed and closed at one end for easy insertion into the firebed and screwed at the other for attachment and replacement. Along the length of the blade there are transverse saw slots or a double row of holes from which the gas and air mixture issues and burns. The poker is connected to the gas supply by a flexible metallic tube.

When used for lighting open fires, fuel is heaped on to the grate; the poker, previously lighted, is inserted into the bottom of the fuel bed and left till ignition of the fuel has taken place. Similarly, when used for lighting coke-fired boilers, coke is placed in the boiler and the lighted poker inserted in the lighting hole (if one is provided) or otherwise into the bottom of the fuel bed. It is generally necessary for the poker to remain only for ten minutes or so, according to the kind of fuel in use, before ignition of the fire is far enough advanced to be rendered self-supporting. The gas consumption is usually of the order of 25 cu. ft. per hour.

GEYSER. *See* Hot Water Supply: (4); Instantaneous Gas Water Heaters.

GLAZIER. In addition to windows and door panels the glazier may be called upon to fix internal glass tiles, external

wall facing, or to build walls of glass bricks. The instructions included in a specification will, of course, have to include every part of his work, and in each section the materials, methods of glazing and workmanship required must be given in detail. If it is desired to use all British glass, the following clause has been suggested: "All glass is to be of British manufacture, of the type, quality and thickness required by the architect. The glazier shall, if called upon, produce invoices to show that he has bought the glass from the manufacturers either in the form of cut sizes or stock sizes for cutting up in his warehouse."

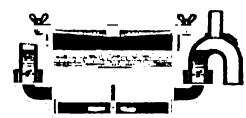
Types of Glass. The thickness and quality of sheet and plate glass and the surface required for plate glass must be stated, as well as the sizes of pane for each position. It is sometimes required that samples be shown to the architect in advance. Figured and textured glass is specified by name, and it is advisable to state whether the panes are to run horizontally or vertically. Special glass such as wired glass, coloured glass, "Vita" glass, must be described in such a way that there can be no mistake about the quality, size, or characteristics required.

Glazing. The following instructions should be given: type and use of putty; description of any special insulation required against temperature changes or noise; making of butted edges; use of wood and metal beads; edges of plate glass to be blackened, and the glazing of all door panels to be bedded in wash leather or india-rubber. All glazing that is of the same size, of the same glass, and carried out in the same way is specified together; but special glazing such as leaded lights, patent roof glazing, electro-copper glazing, stained glass, pavement lights, etc., must be specified each under separate clauses. A schedule of all glazing to be done, with positions shown on plans, is included.

B.S.S. No. 544. "Linseed oil putty (Types 1 & 2) for wooden and metal frames."

GLOBE TAP or Globe Cock. A variety of tap used chiefly for baths. The union is on one side of the globe, so that the supply pipe enters at a right angle to the tap. The valve, globe and nozzle of the tap are in a vertical line. This type of tap is unsatisfactory for sinks and basins, as there is little clearance between the wall or side of the sink and the tap. (*See* Tap.)

GREASE TRAP AND GULLY. A special trap or gully to intercept grease, necessary where large quantities of grease (as from wash-up sinks) would otherwise enter the drain, to congeal and probably clog it. The trap should be manufactured of glazed stoneware, cast-iron, concrete or other suitable material, and be fixed between the sink or sinks and the drain, in a readily accessible position.



GREASE TRAP. Fig. 1. C.I. grease trap suitable under sink, 18 in. x 12 in. x 12 in.; 2-in. inlet and outlet; w.i. sediment pan. *Burn Bros. Ltd.*

The grease contained in the discharge from the sink is congealed by the cooling action of a sufficient quantity of water in the trap. A galvanized and perforated tray should be fitted to or in the bottom of the grease chamber, with one or more handles long enough to reach above the water level, so that the congealed grease may be periodically removed as required. This is done by lifting out the tray. The outlet is below the perforated tray, so that no solid matter can pass into the drain. The top of the grease chamber should be made airtight with a sealed cover, and be ventilated into the open air to prevent obnoxious gases from entering the apartment. Access to drain is by an inspection eye with screwed plate.

Grease Gullies. Gullies for use in conjunction with an automatic flushing tank, are provided with flushing rim and connexion for flush pipe. Discharge from the tank breaks up the congealed grease

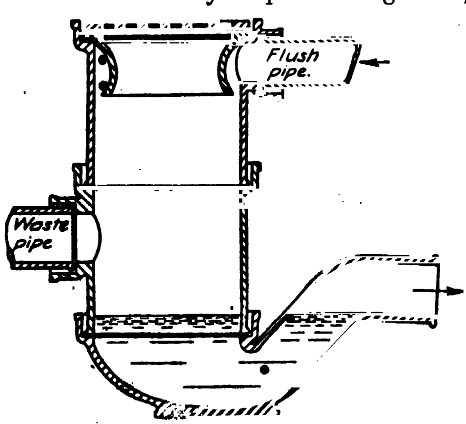
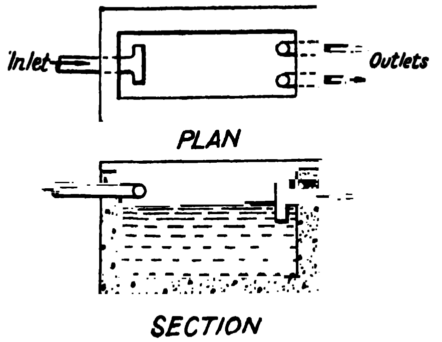


Fig. 2. C.I. grease gully with connexion for flush pipe from automatic flushing tank.

and carries it in a congealed condition to the drain. The flush also cleans the gully and flushes the drain. —*W. J. Woolgar.* *See* Trap; Hotel.

GRIT CHAMBER: or Detritus Tank. In sewage treatment, a tank in which the heavy mineral particles in sewage are settled out. These particles, which are mostly sand and grit washed from roofs, yards and streets by rainwater into "combined" sewerage systems, have a fairly high specific gravity and can be settled out by a slight checking (*i.e.* reducing) of the velocity of the sewage. The organic suspended matter should not be allowed to settle in the grit chamber in any quantity, but should pass through for subsequent treatment (*see* Sewage Treatment).



GRIT CHAMBER. Fig. 1. Detritus tank in which heavy particles settle from sewage; suitable to serve a few houses (compare Fig. 3, page 403).

In all but the very smallest sewage treatment works, two grit chambers should be provided, one to take the flow in dry and showery weather and the other to be brought into operation during storm conditions—either automatically, as by means of a weir, or by the use of sluices, valves or penstocks. Each grit chamber should have a capacity of about one-hundredth of the daily dry-weather flow.

The length may be three or four times the width, and the depth one or two feet below the invert level of the inlet and outlet channels, with an additional depth for storage of grit. The quantity of grit to be dealt with varies considerably, but an average quantity is from 10 to 20 cu. ft. per million gallons. Figs. 1 and 2 show typical grit chambers for works serving a few houses and a large village or estate respectively.

Grit chambers should be cleaned out regularly, and as soon as possible after a storm. If sufficient fall is not available for chambers to be emptied by gravity, the deposit should be lifted out by means of a chain pump (*see* Cesspool).—*W. H. Hillier, M.Eng., A.M.Inst. C.E.*

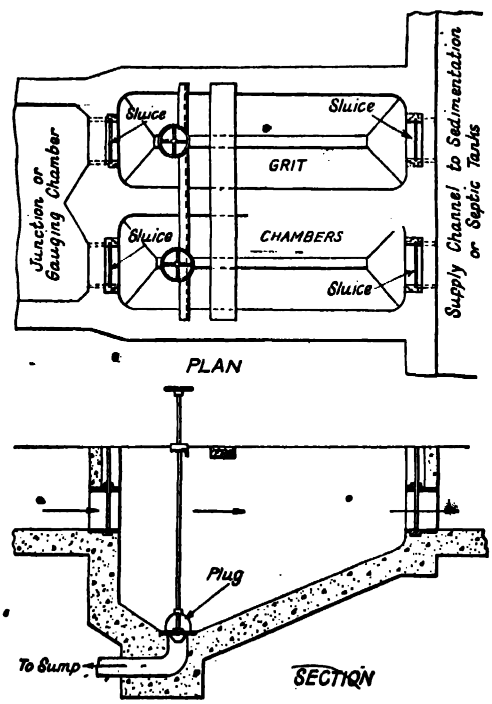


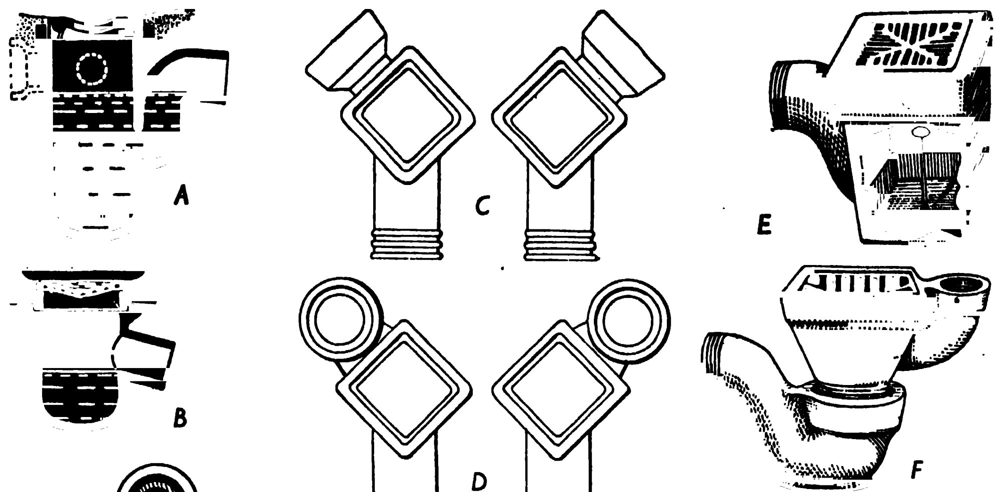
Fig. 2. Grit chambers for large village or estate. Fall of tank bottom is longitudinally towards inlet; sludge plug is operated by hand wheel above tank, and sluices regulate flow through chambers.

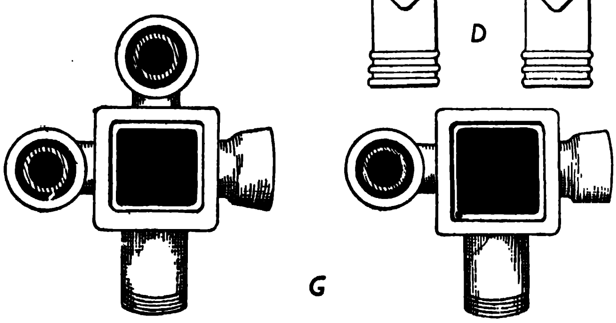
GULLY. A fitting placed at the end of a drain line to receive water or waste discharges, or for the collection of surface water from buildings or roads.

The fittings are obtainable in stoneware or cast-iron; in the first case they are glazed to give an impervious surface, and in the case of cast-iron gullies they are coated with a bitumastic solution for protection against corrosion.

Both trapped and trapless gullies are used. The trapped gully is so formed as to contain a quantity of water in the base, thus disconnecting the fitting from the drain line by means of a water seal and preventing foul gases escaping.

Stoneware Gullies. The common type of trapped gully made in stoneware is square at the inlet and tapering to round at base, the top edge being rebated to allow a grating or cover to be fitted. Branches are made on the inlet side, either horizontal or vertical; these branches on the square, one-piece fitting are limited to three sides, being respectively R.H., L.H., or back inlets.





GULLY. Fig. 1. Stoneware fittings: A, trapped yard gully with hinged grating; B, untrapped yard gully with square dished top; C, horizontal inlets to gully having outlet on the angle; D, vertical inlets to similar gully (*Doulton & Co., Ltd.*); E, mud interceptor showing bucket in position; F, reversible gully with 3-in. N inlet; G, yard gullies with horizontal and vertical inlets, to be fitted with gratings (*John Knowles & Co., Ltd.*)

When more accurate fitting to position is needed than the common trapped gully will allow, traps are used with the gully inlet as a separate piece. This method allows the trap to be positioned and the gully inlet turned to the desired direction; jointing is then made to suit. The joint is usually in the water seal of the trap, and care must be taken to ensure a watertight joint and to remove all surplus jointing material from inside the fitting.

In the case of a trapped gully to receive surface water over an area from which solid and floating matter, such as mud, leaves, etc., might be conducted to the drain, provision must be made to intercept this and avoid it passing into the drain system. Fittings are made up for this purpose with a deep well to act as a settling base to receive sludge; also, perforated containers known as sediment-pans are fitted to collect the solid matter.

These gullies range from 9 in. dia. × 18 in. deep to 24 in. dia. × 42 in. deep.

Cast-Iron Gullies. These are made in a one-piece fitting, or in two units (that is, the trap and inlet separate). A wider range is available for branch inlets, due partly to the fitting being more compact and easier to manufacture. With sufficient depth available at the trap invert, practically any branch inlet can be connected by using suitable raising pieces with branches cast on.

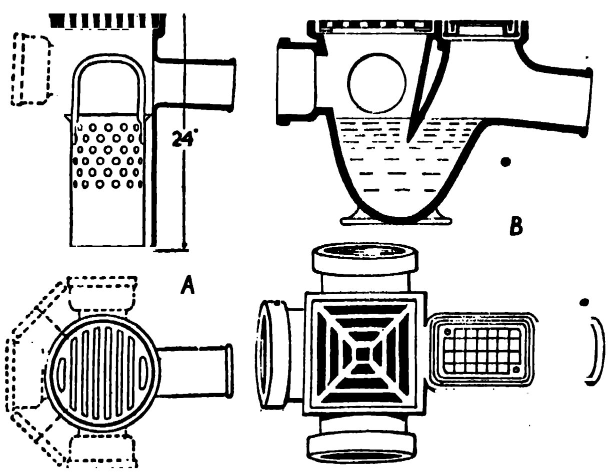
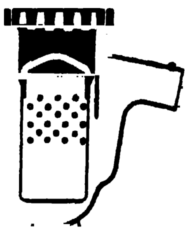


Fig. 2. Cast-iron gullies; A, trapless gully, suitable for yards and garages where a series of gullies is connected to master trap: 9 in. diam. by 24 in. deep, 10½ in. heavy grating, 4 in. P outlet, galv. w.i. perforated sediment pan, 4 in. inlet sockets cast on in any of positions shown (*Burn Bros., Ltd*); B, gully trap, access over outlet with luted cover: 4 in. by 95 deg., 9 in. by 9 in. top, 14 in. high. (*Cameron and Roberton, Ltd.*)



GULLY. Fig. 3. Dean's trap: 9 in. diam., 24 in. deep, 4 in. P outlet only. *Burn Bros., Ltd.*

Various patterns of deep-well fittings are made for sludge collection, the general design being similar to that previously described.

Trapless Gullies. These fittings are used for collection of liquids when the disconnecting of foul gases has been safely dealt with by a trapped gully. Assuming that a drain line is so placed that further fittings are required to receive heavy discharges adjacent to a trapped gully, it would be safe to fit a trapless gully. The same applies if conditions are such that the drain line would not be satisfactorily ventilated if continued to a position required and the point of collection was of uncontaminated liquid; in such a case the connecting drain line would not become foul and give off an offensive smell.

The cases described are more common when dealing with drainage systems of town buildings. A fairly common practice is to fit a master trap with gully inlet from which branches would be taken to various positions. When deciding such positions, consideration must be given to various fittings which are to discharge into the master gully; and it must be borne in mind that the foul water surface, if any, may be ventilated back through the branch inlet to which the trapless gully is connected.

When dealing with drainage of areas that are in contact with inflammable liquid, such as petrol or oil, the collection of surface water must be dealt with in an entirely different manner. A petrol interceptor is required, and there are various other special points, these being explained under Garage Drains (*which see*).

Access. In order to facilitate cleaning, or rodding, in the event of a stoppage, traps are made with cleaning doors that are airtight and integral with the fitting. This type of fitting should be used wherever necessary, and will justify its additional cost.

Where gullies are positioned to receive waste discharges from high buildings and no low-level fittings are connected, and the inlet is not required for surface drainage, it is advisable to fit a sealed cover and not a grating. This method avoids the heavy foam which always occurs when a bath is discharged, but can be used satisfactorily only when the inlet is ventilated, as it would be by the connexion of a ventilated waste pipe.

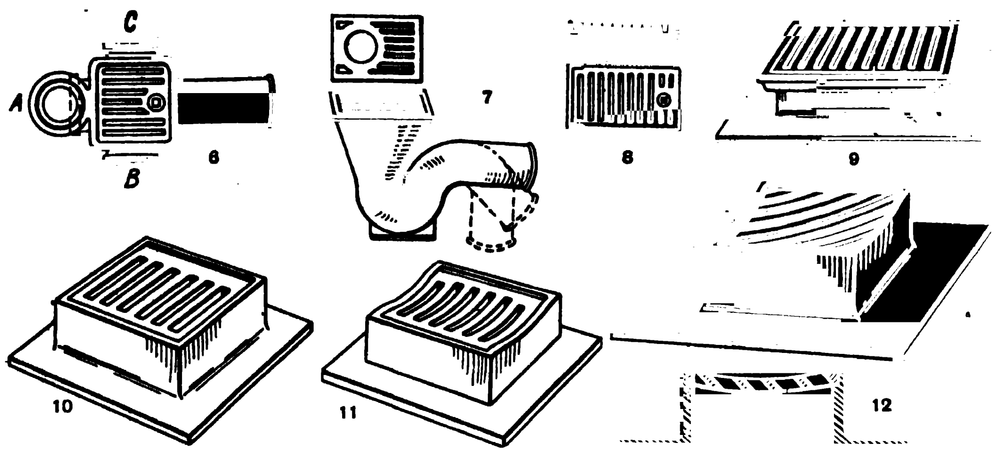
Branches. Although fittings are made to which any normal angle of branch can be connected, and several branches if required, the outlet of the fitting is capable of carrying only a certain maximum load. In the case of a fitting positioned to collect waste and rainwater discharges to the drainage system (assuming this is a combined drain), the total area collected with the rainwater pipe must be given full consideration, and calculations made to prove that this would not be overloaded in the event of a heavy storm.

Overloading may be remote, but in the event of the fitting being placed inside the building and fitted with a sealed cover, flooding would occur at the lowest fitment connected if the flow were more than the gully could cope with.—*R. J. Audrey, M.R.San.I.*

See Drains; Gully Gratings; Traps.

GULLY GRATINGS. Made to suit various types of gullies, those for the standard bellmouth being 8 in. diameter by ½ in. thick (Fig. 1) and intended for foot traffic only. Similar gratings are made 10½ in. diameter to suit bellmouths and extensions of H.M. Office of Works pattern gullies; but as the sockets of these fittings are 1½ in. deep, an outside rim is provided to give a seating in the socket. Fig. 2 shows such a grating applied to an extension. Owing to the depth of the socket of the extension mentioned a heavy grating having bars the full depth (Fig. 3) may be fitted so that if the appropriate grating is selected the extension may be used for foot or vehicular traffic.

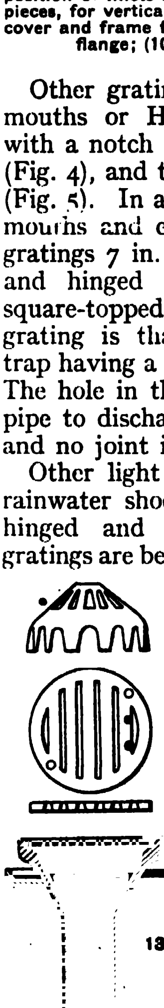
GULLY GRATINGS. Figs. 1–5. (1) standard bellmouth grating, 8 in. diam. by ½ in. thick for foot traffic only; (2) grating 10½ in. diam. in extension or raising piece 9 in. diam.; (3) grating 1½ in. thick to fit socket of extension piece (2) for heavy traffic conditions; (4) light, 10½ in. diam. grating with pipe notch; (5) light, 10½ in. hinged and locking grating. (*Burn Bros., Ltd.*)

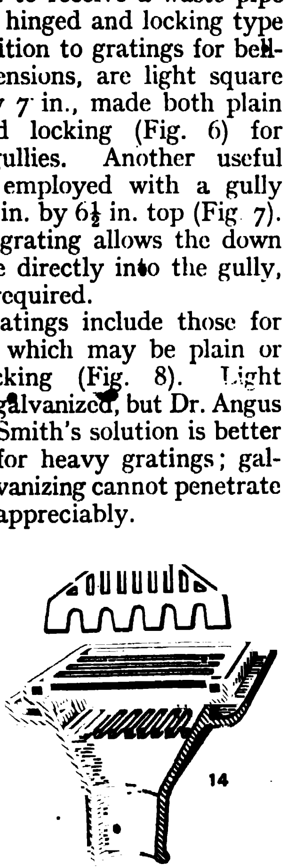


GULLY GRATINGS. Figs. 6–8 (*Burn Bros., Ltd.*): (6) square top gully trap with 7 in. by 7 in. locking grating, position of inlets shown by A,B,C; (7) top and side view of gully trap with 9½ in. by 6½ in. grating, trap in two pieces, for vertical down pipe and surface water, 4 in. outlet; (8) side and top view of hinged and locking cover and frame for rainwater shoe. Figs. 9–12 (*Carron Co.*): (9) gully grating 12 in. sq. on 21 in. sq. bottom flange; (10–12) box grates cast in one piece with flat, concave, and louvred gratings respectively.

Other gratings used for standard bell-mouths or H.M.O.W. gullies are those with a notch cut to receive a waste pipe (Fig. 4), and the hinged and locking type (Fig. 5). In addition to gratings for bell-mouths and extensions, are light square gratings 7 in. by 7 in., made both plain and hinged and locking (Fig. 6) for square-topped gullies. Another useful grating is that employed with a gully trap having a 9½ in. by 6½ in. top (Fig. 7). The hole in the grating allows the down pipe to discharge directly into the gully, and no joint is required.

Other light gratings include those for rainwater shoes, which may be plain or hinged and locking (Fig. 8). Light gratings are best galvanized, but Dr. Angus Smith's solution is better for heavy gratings; galvanizing cannot penetrate appreciably.





Figs. 13 and 14. Gratings to roof gullies: (13) elevation of domical, and plan and section of flat gratings for circular gully; (14) domical and flat gratings to rectangular outlets of gully to suit L.C.C. or large-socket R.W. pipes. (*Burn Bros., Ltd.*)

Yard and Garage Gullies. These all have heavy gratings to suit their tops, and ranging from 9 in. by 15 in. diameter. A convenient gully grating 12 in. by 12 in. square with 21 in. by 21 in. bottom flange is shown by Fig. 9. A rectangular gully may have its top below the surface and an extension can be built in brickwork (through which the branch drains enter) and the grating is then bedded on the top.

Gratings for Road Gullies. These require to be very strong, and large enough to allow of the insertion and withdrawal of a sludge scoop or pump suction pipe. They are made curved (Fig. 11), flat (Fig. 10), and louvred (Fig. 12), and sizes vary from 8″ × 6″ clear opening with 1[illegible] × 13″ bottom flange to 16½″ × 13″ clear opening with 26½″ × 26½″ bottom flange. The grating thicknesses vary from 1½″ to 3″ and the total depth of frames from 2½″ to 6″, according to size. If fixed in road gutters the curved pattern is desirable, and the curved louvred pattern is probably the most efficient. Hinged gratings are convenient, but there is some danger of their breaking when dropped into place after raising. The bottom of flange of roadway gratings is bedded on concrete or brickwork laid between gully top and road surface.

Roof Gullies. The gratings resemble in the main those for surface gullies and are rectangular or round according to the type of gully. Domical gratings are frequently used in place of flat gratings on roofs where there is no foot traffic.

The domical grating gives a better water way and it is not likely to become choked by debris, leaves or paper. Flat and domical gratings are shown applied to a circular roof gully in Fig. 13, and to a rectangular roof gully in Fig. 14.

GUNMETAL. Name applied to a range of copper-tin alloys in which the tin content may vary from 5 to 12 per cent. The most widely used alloy, however, is that containing 10 per cent. of tin, but in this material the properties vary very considerably with the method of production. Thus, when sand-cast the tensile strength is approximately 15 tons/sq. in., but when pressure casting is adopted the strength may be as high as 32 tons/sq. in. Chill casting also has the effect of improving the strength and thus a tensile strength of 18 tons/sq. in. is common for chill-cast gunmetal.

Admiralty Gunmetal. The Admiralty Specification for gunmetal covers an alloy containing copper 88 per cent., tin 10 per cent., and zinc 2 per cent., the zinc thus replacing some of the copper in the standard 10 per cent. tin-bronze. This composition is adhered to for Admiralty work, but as supplied to the trade generally the material may contain more zinc, and additions of lead. The 88 : 10 : 2 Admiralty gunmetal has a minimum tensile strength of 14 tons/sq. in., with an elongation of 7·5 per cent., but these extra additions of zinc and lead, while they certainly render casting more easy, lower considerably the strength of the material. For this reason a tensile strength no higher than 12 tons/sq. in. will normally be shown by them, and their elongation usually falls to 5 per cent. or even lower.

Gunmetal is not recommended for service at elevated temperatures, as the properties deteriorate rapidly and the metal is of no value for components subject to superheated steam. Annealing at about 700° C. renders gunmetal castings less porous to water or oil under pressure, and increases ductility. For steam valves, a gunmetal containing copper 85 per cent., tin 10 per cent., and lead 2 per cent. is superior in its resistance to steam and is widely used for these purposes. Nickel up to 1 per cent. is also sometimes added to gunmetal, as it gives a finer grain and increases both the strength and the hardness. It also helps in preventing the segregation of any lead also present. In fact, gunmetal in which the combined tin and nickel contents exceed 10 per cent. is far superior to the 88 : 10 : 2 gunmetal in temperature resistance, as, for instance, in steam valves, cocks and other steam fittings. For valves and fittings subject to the action of corrosive waters the nickel content should be increased.

GUTTERS: (1) LEAD, THE CHIEF TYPES

By T. Jennings, M.R.San.I., R.P.

This contribution explains the construction of the chief types of gutter in leadwork. It also summarizes the essential requirements of the gutter woodwork. Box Gutters are dealt with elsewhere in this work under their own heading. See under Rainwater Drainage for principles of gutter drainage, and for capacities and fall of gutters ; *also* under Roofwork : (1) in Lead for general notes on gutter work.

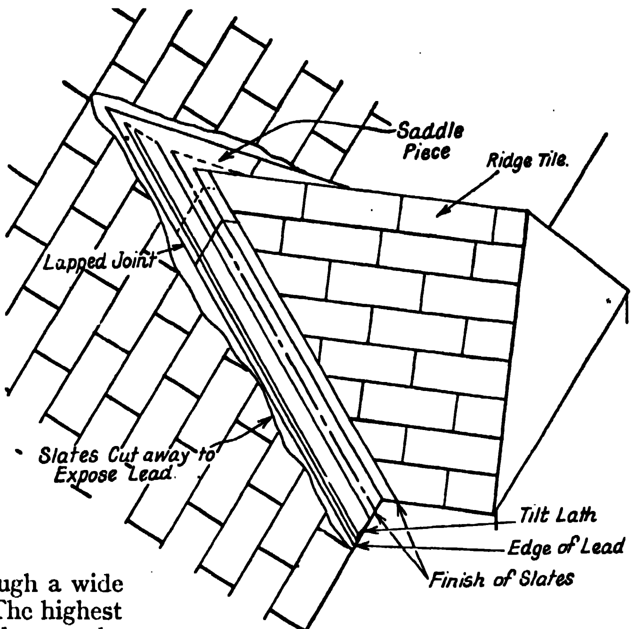
Lead gutters are formed wherever the inclined portion of a roof alters its direction, or two adjoining parts of the roof intersect at such an angle as to render it impracticable to weather the junction satisfactorily by means of ordinary flashings. The gutters convey the roof water to the outlet and R.W. pipe.

The chief types are here dealt with briefly. Additional information is given in the article Roofwork: (1) in Lead, and its associated Plate. Methods of setting out gutters are there shown. Lead gutters vary in their types and names, but generally speaking they may be divided into two classes: those fixed at relatively steep pitch or angle, in which case the joints are simply overlaps or passings—the overlap being *at least* 4 in., and those fixed with as little fall or incline as practicable, the minimum being 1½ in. in 10 ft., or 1 in 80. In the latter case the joints have to be more carefully arranged to ensure a satisfactory job. The most usual method of joining the bays in horizontal gutters is by means of the drip (*which see*).

Hip Valley. Taking them in the above order, we have first the hip valley or V-gutter, which is the most usual method

of weathering the junction of a hipped roof with the main roof (Fig. 1). These gutters are fixed in lengths equal to the usual widths of lead sheets—7 ft. to 8 ft.—and vary from 15 in. to 22 in. wide according to the type of roof covering (slates or tiles) and the type of gutter (close or open). They are fixed on gutter boards provided for them, and a tilt lath is usually fixed longitudinally, although in many instances, especially where small flat tiles are used, the slater may prefer a bead turned on edge to allow him to adjust height and prevent tiles being tilted the wrong way. Both tilt lath and bead are shown in Fig. 2.

Fig. 2A shows a section through a wide flat type of hip valley gutter. The highest part of this gutter is continued upwards,



GUTTERS : LEAD. Fig. 1. Double hip valley or V-gutter, such as is used with a dormer, showing tilt lath under slates to give correct angle, and separate saddle piece overlapping lead join at apex (see also Figs. 2, 2A and 3).

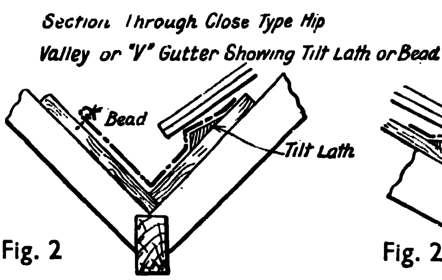


Fig. 2

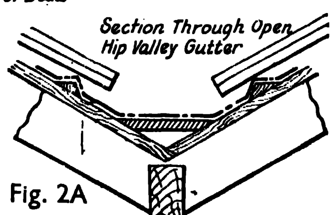


Fig. 2A

Fig. 2. Section through close type V-gutter, showing lead dressed over tilt lath on right and turned over to form bead on left, resting on gutter boards, and with slate fixed over lath. Fig. 2A (right). Section through open hip valley gutter showing lead dressed over two laths, and resting on lear and sole boards.

in the case of a single gutter, and tiled over; or, as in the case of the double hip valley (Fig. 1), both tops are turned over the "apex" to render it watertight.

Sometimes a separate *saddle piece* (Fig. 3) is made and fixed at this point overlapping the tops of the lengths, the same as in an ordinary join—namely, at least 4 in.

This V-gutter can also be formed with small pieces of lead similar to soakers, fixed with each course of slates, as shown in Fig. 4. In this case the gutter is very close and practically invisible, but involves more lead and labour than straight lengths.

Secret Gutters. Shown in Figs. 5 and 5A, p.486. *See also* under Roofwork: (1). They are sometimes fixed along the sides of chimneys, or other projections through roofs, in the direction of the "fall." The advantage attributed to these gutters is the additional safeguard against the penetration of water under the slates, afforded by the lath which is fixed longitudinally, forming a channel for the water.

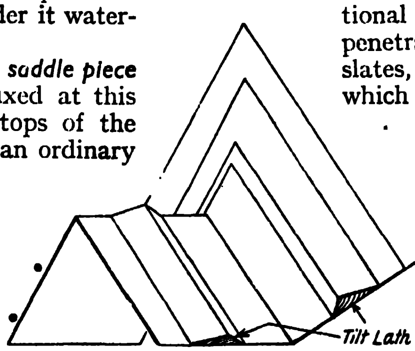
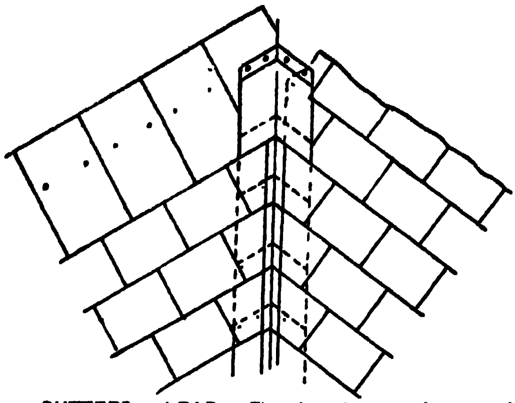


Fig. 3. Saddle piece dressed over tilt laths for apex of double hip valley gutter, as used in Fig. 1.

The objection to these gutters is that they are prone to become choked with silt and leaves. But this objection diminishes as pitch increases. They vary in width from $1\frac{1}{2}$ in. to 3 in. In the case of the

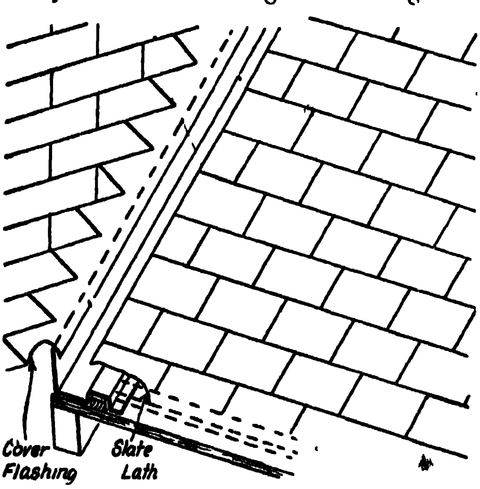


GUTTERS: LEAD. Fig. 4. V-gutter formed of soakers, fixed with each course of slates and with overlap in direction of fall, soakers being cut about 4 in. each side of angle (see p. 485).

narrow gutters they can be cut and fixed in one piece, or "self-flashed."

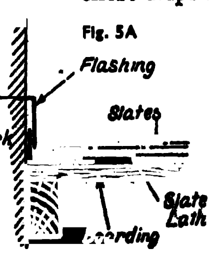
Parapet and Valley Gutters. As these gutters (Figs. 6-8) are fixed nearly horizontally, and involve different preparation and methods of joining, much care must be exercised in their fixing. (*See also under headings* Box Gutter; *and* Roofwork).

Specification for Joiner's Work. As the final responsibility for the lead-lined gutter rests with the plumber, it is often stipulated by the architect that details for these gutters must be furnished to the joiner in the setting off of the gutter



Figs. 5 and 5A. Elevation and section through secret gutter between slates and brickwork, as used beside chimney, showing slate lath, lead lining to gutter, and cover flashing dressed up chimney and tucked into brickwork (see p. 485).

woodwork. Therefore, the plumber should know what are the main essentials to ensure a good job. They can be summarized as follows:



Gutter should be substantially constructed to carry weight of lead, traffic, and snow without movement.

Smooth surfaces must be formed with all edges and corners rounded off and nails well punched in. Boards should be as narrow as possible—about 4 in.—to

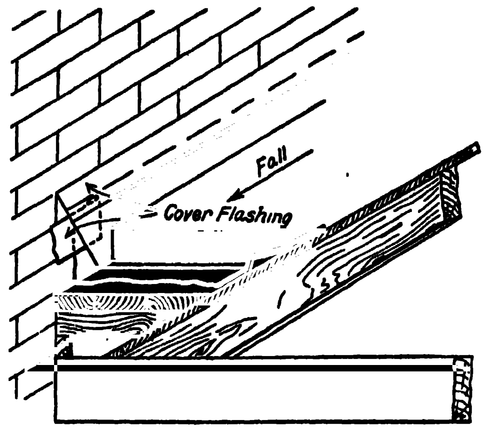


Fig. 6. Parapet gutter formed where lower edge of pitched roof abuts a wall; drips are 2 to 3 in. deep; tilt fillets under slates ensure watertight join to lead; lead is carried up slope to vertical height equal to that of upstand against wall; upstand is protected by cover flashing (see Fig. 7, p. 487, *and also* Figs. 1–5, pp. 339–340).

prevent corrugations being formed when the wood warps; fixed with the heart side upwards and the grain running in the direction of the flow of water.

The gutter should be designed to permit air circulation under boards to prevent rot.

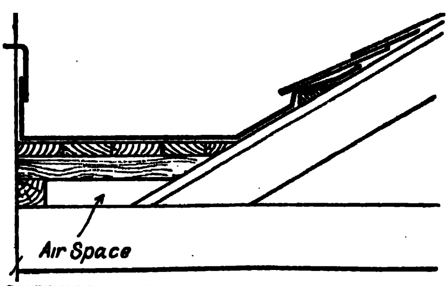
A good tilt lath or tilt fillet should be fixed whenever slates join the lead, in order to ensure a watertight joint by tightening the lower courses of the slates and also preventing any drift under them.

The fall or inclination of the gutter boards towards the outlet should never be less than $1\frac{1}{2}$ in. in 10 ft. The outlet should be 12 in. wide. Joints across the gutter are formed by means of drips, which should, if possible, be 3 in. high and never less than 2 in., with a splash lap 1 in. wide on overcloak. The distance these drips are apart determines the length of the bays, but it should never exceed 10 ft. This detail varies with each job, on account of dividing the total length of gutter into equal divisions, or working drips to suit width of sheet.

The amount of lead exposed in one piece should

not exceed about 18 sq. ft., although in some cases 24 sq. ft. can be permitted with safety.

Generally speaking, the smaller the pieces are, the better, but it must be remembered that in the case of gutters every extra bay involves additional height and width as incline increases (*see* Box Gutter, Fig. 2).



GUTTERS: LEAD. Fig. 7. Section through parapet gutter of Fig. 6; lead is dressed over fillet on slope, and upstand is weathered with cover flashing; air space below gutter board prevents rot.

the requisite height, but in some cases 12 in. may be advisable. It should be obvious that the vertical height to which this should be taken must be at least the height of upstand against the wall (*see* the illustration of a parapet gutter in Fig. 6).

Fixing Details. When the woodwork is ready to receive the lead, the lowest bay is the first fixed and then the others in ascending order.

Apart from details of the drip, the next important matter is the distance to which the lead is taken up the inclined part of roof. This length is usually 9 in., to give

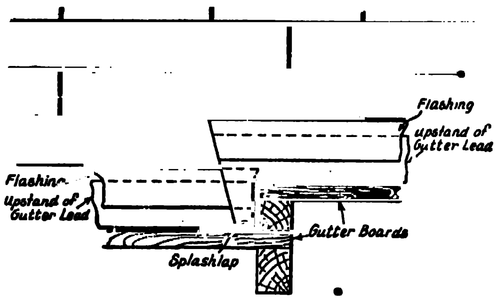


Fig. 8. Section through parapet gutter, showing flashing to parapet or wall and drip detail (*see also* Figs. 6 and 7).

The foregoing details apply to: (1) valley gutters which are formed where roofs of the same or different pitches join each other along their lower edges (as section, Fig 2A); (2) parapet gutters which are formed where the lower edge of a pitched roof joins a higher building, or a special parapet wall built as an architectural feature. The detail of this gutter is shown in Figs. 6, 7 and 8. In both these gutters the number of outlets and falls towards them has to be set to suit the particular conditions; also in some cases the width of the gutters may involve the need of two bays with a roll fixed longitudinally, to divide it into two pieces of the maximum area allowed.

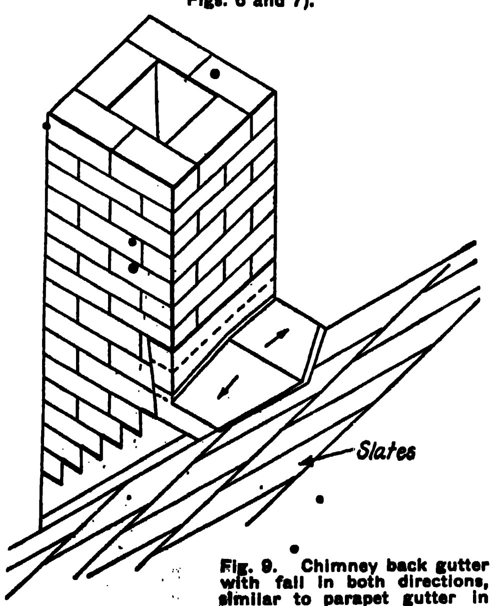


Fig. 9. Chimney back gutter with fall in both directions, similar to parapet gutter in Figs. 6 and 7, with chimney side gutter as in Fig 5.

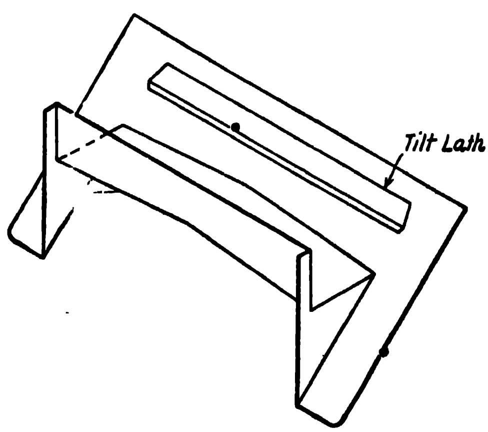


Fig. 10. Lead for chimney back gutter (Fig. 9), with upstand to chimney in front and cover flashing omitted, showing position of lath.

Chimney Back Gutters. These (shown in Figs. 9 and 10) are fixed whenever a chimney or similar projection penetrates a pitched roof. The details are similar to those of a parapet gutter. Usually they are fixed in one piece, turned down on to slates at each end, and when more than 2 ft. wide should be made with a fall each way, as Fig. 9. Fig. 10 shows view of lead. *See also* under Roofwork: (1).

GUTTERS: (2) CAST-IRON, STEEL, ASBESTOS, ALUMINIUM & COPPER

By D. Longden, M.R.San.I.

The most important types of gutter are here described, with the fittings in common use. For general principles of gutter drainage see Rainwater Drainage.

See *also* Aluminium ; Asbestos Cement ; Copper.

British Standards covering gutters are

Cast Iron Gutters, Fittings and Accessories, Half Round Gutters B.S. 1205, Part 1, 1945. O.G. Gutters B.S. 1205, Part 2, 1945.

Asbestos Cement Gutters B.S. 569, 1945.

Pressed Steel Galvanized Rainwater Gutters, Pipes and Fittings B.S. 1091, 1946.

Aluminium Rainwater Goods, cast and extruded B.S. 1430, 1947. B.S. 1543. 1949. Wrought aluminium rainwater goods.

Rainwater Goods Wrought Copper and Wrought Zinc B.S. 1431, 1948.

These gutters of different materials resemble one another very closely. They are all spigot and socket in approximately the same lengths, 6 ft. being the maximum. Fittings are similar in dimensions though pressed steel are somewhat longer. All gutters are as light as manufacture permits. Gutters and fittings are holed in the bottom to receive small countersunk screws. The diagrams (Fig. 1) show fittings common to all materials with terms for both O.G. and H.R. gutters. Diameters are 3, 4, 4½, 5 and 6.

In addition cast-iron gutters for large buildings are made in numerous patterns and makers' lists should be consulted. The modern trend is to use copper for large office buildings and the like, and pressed steel for factory gutters, often purpose made.

Valley Gutters, Steel. Pressed steel is favoured for large valley gutters to factory roofs since it is relatively light and is easily fixed to the structural steel work. These gutters are of heavier metal than the B.S. mentioned, $\frac{1}{16}$ in. being general instead of 20 B.G. of the Standard. Valley gutters should always be of ample width to allow repair work to be carried out from them, and they should serve as walking ways. Fig. 2 shows a typical steel valley gutter. Note that the outlet is belled in order to allow water to run freely away. Whilst most gutters require a fall of 1 in. in 10 ft. these large gutters only require 1 in. in 25 ft. The sides of the gutter must be high enough to prevent storm water entering the building. Box and boundary wall gutters are also made in pressed steel.

Asbestos Cement Gutters. Also used for valley, boundary wall and box gutters. They are not as satisfactory for valley gutters as pressed steel but for the other two purposes are equally so. These gutters are covered by B.S. 569: 1945. (*See also* page 73). Valley gutters for roofs of equal slopes are included in the Standard.

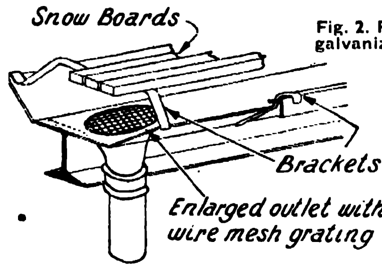
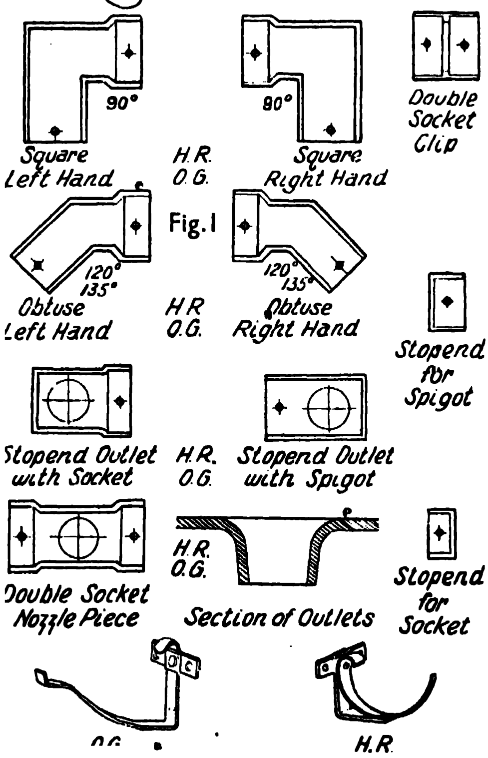


Fig. 2. Pressed steel galvanized gutter.



GUTTERS, CAST-IRON, etc. Fig. 1. H.R. and O-G. with fittings according to B.S. 1205, 1945, Parts 1 and 2, for C.-1. gutters, fittings, and accessories. Mild steel brackets shown at bottom. The number of fittings has been limited in this Standard to facilitate production.

The three types are covered in 5 Tables: *valley*, 6 and 18 and 24 and 12 in. wide (inside, top), 5 and 6 in. deep, ½ in. thick; *boundary wall*, 11, 12 and 16 in. wide (inside, top), 5 and 6 in. deep, ⅜, ⅝ and ½ in. thick; *box*, 5, 12 and 15 in. wide (inside, top), 4½, 6, 8 and 5 in. deep, ⅜ and ½ in. thick.

Asbestos cement valley, boundary wall and box gutters are made spigot and socket, the latter being 4 in. deep. They are not holed for screws and bolts because they are intended to rest on a bearing surface.

Asbestos Cement Fittings are standard for the above three types of gutters and are as follows:

Drop ends which seal off the end of the gutter provide an outlet and have a socket to receive the last spigot length of guttering. They are 15 in. long effective and may have outlets 4 in. and 6 in. internal diameter.

Nozzles for connecting two spigot lengths in a mid-position, 15 in. effective length with outlet 4 in. or 6 in. internal diameter.

Angles (internal or external) for use at corners of buildings. These are made with a socket at each end.

Stop ends for Spigots to receive spigots ends of guttering and seal off the end of the gutter when an outlet is not required.

Stop ends for Sockets to fit socket ends of guttering and seal off the end of the gutter when an outlet is not required.

Jointing. Asbestos cement gutters may be jointed with cement or with a bituminous compound obtainable from the manufacturers.

Fixings of Gutters (All Types). Small eaves gutters may be fixed to fascia boards by means of mild steel brackets screwed to same. Half round gutters may be fixed with straps to rafters but this is not possible with O.G. gutters. O.G. gutters may be holed at the back to receive No. 12 countersunk head wood screws for fixing to fascia boards. The new British Standard design keeps the screw hole above the water line, thus avoiding rotting of the fascia board. Brackets for these gutters must depend entirely upon position and weight of gutter and be designed for each particular position.

Jointing of Gutters. Cast-iron and pressed steel gutters may be jointed by means of red lead and putty or cementatious cold caulking compound. The latter material is suitable for asbestos gutters but the makers provide their own cement compound, or bituminous preparation.

Aluminium Gutters. Cast and extruded, covered by B.S. 1430, 1947. O.G. and H.R. gutters are illustrated, with brief notes, *under* Aluminium, p. 49. Standard length, 6 ft. Sizes, H.R. 4 in., 4½ in., 5 in., 6 in.; O.G. 4 in., 4½in., 5 in. Thicknesses are given in page 49. Fittings and accessories may be cast in one piece, extruded with formed socket, or cast with a cast socket. They should not be mild steel.

The fittings for H.R. gutters are angles, square and obtuse both left and right hand, outlets with socket and stop end, outlet with spigot and stop end and double socket nozzle pieces.

Nozzle outlet diameters are 2⅝ in., 2⅞ in., 3⅞ in. for 4—4½ in. 5 in. and 6 in. respectively.

The fittings for O.G. gutters are angles, square and obtuse for external and internal angles, spigot and socket nozzle pieces, drop end for spigot and drop end for socket.

Both half round and O.G. gutter sockets are slot-holed ¼ in. diameter × ½ in. long to receive $\frac{3}{16}$ in. bolts.

O.G. aluminium gutters are holed at the back for fixing to fascia boards, but this method is not recommended.

Copper Gutters. Copper sheet or strip, folded to the required shapes, make durable but light eaves gutters. The sections available are half round, rectangular and O.G. They are obtainable in lengths of 6 ft., 7 ft. and 8 ft., and according to size are either 22 s.w.g. or 24 s.w.g. The range of sizes are 3 in., 4 in., 4½ in. and 5 in.

The range of copper fittings (B.S.1431) is:

Stop ends: Used at the ends of gutters.

Angles: Both internal and external, right-angled.

Outlets: For connexions to the rainwater pipe.

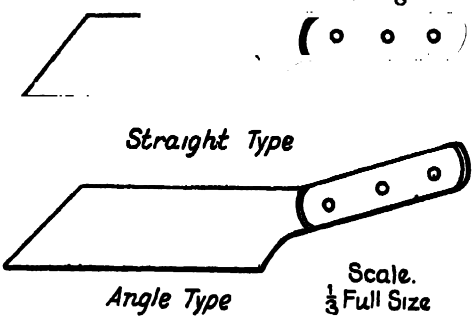
Gutters can be secured to the fascia by means of screws inserted through tubular stays, placed every 30 in. or by means of fascia or spar brackets of copper or copper alloy.

Joints are plain-lapped and soldered for a minimum distance of 2 in., the ends of the gutters being pre-tinned before fixing. Alternatively, with certain types of gutters, clips are supplied which are filled with a bituminous compound making a watertight joint. This is recommended.

Wire balloons should be fitted at the outlet of all gutters. They should be of ¾ medium mesh 16 W.G. with 13 W.G. frame.

HACKING KNIFE: or Chipping Knife. Stout knife for chipping off old hard putty from round window frames when replacing glass, or hacking thick pieces of sheet lead or lead pipe. It has a robust steel blade about 4 in. long and 1¼ in. wide, and handle continuing the blade, but reduced to about ¾ in. wide. To each side of the handle is riveted a strip of leather to protect the hand when in use. The knife may be obtained in two types,

one with the handle at an angle to the blade and the other with the handle in line with the blade. The hacking knife



HACKING KNIFE. Strong knife with stout steel blade about 4 in. long and 1¼ in. wide; the handle, covered on each side with leather, is a continuation of the blade. Used for soft metal, hard putty on old glazing, etc.

is stronger than the pocket knife or bass knife, and is used by being struck with the hammer on the back edge of the blade.

HACKSAW. Saw for cutting metal. The blade is of good hard steel with set teeth and is held in a shallow bow. The blade is provided with a hole at each end, to engage with pegs on the stems of the bow. Tension is applied by a thumbscrew working on the squared stem farthest from the handle.

Frames. The cheapest type will take a single size (length) of blade—being made in 8, 9, 10 and 12-in. capacity. In several respects the single-size frame is superior; it is more rigid than the commoner adjustable frames, but, of course, the user must provide himself with a supply of blades of the proper length. The bow of the usual type of adjustable frame is made in two pieces, one sliding in the other, and can be extended or shortened within its range to take various lengths of blade—usually 8 in. to 12 in. Unless well made, however, they tend to whip when extended to, say, 12 in., and the alinement may be erratic. The depth under back of ordinary bows is 2½ in. to about 2¾ in., but bows 3⅛ in. and 5⅛ in. deep are made. For cutting large work, hacksaws with a depth under back of 7½ in. and 10½ in. are obtainable, and would be used for cutting off rails, etc. Going to the other extreme, there are many occasions when extra rigidity is an advantage, and a depth of cut of about ¾ in. will suffice. For such occasions the tee-back frame is the most convenient; the back is a tee-section member and the blade is fixed about ½ in. beneath it.

Apart from the points mentioned, the choice of a frame is largely a matter of price. The tool gets hard and frequent usage, and it is worth while purchasing a good frame at the outset. The common type of handle leaves much to be desired, and the improved form ("pistol-grip")

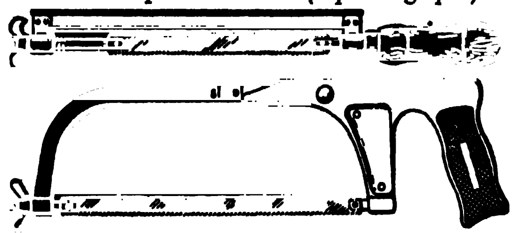


Fig. 2. (top) hacksaw frame with tee-section back for extra stiffness in shallow cutting; (below) extension frame with pistol grip for comfort in handling. *S. Tyzack & Son, Ltd.*

gives a firmer and more comfortable hold. The tubular type of frame also has good points, though it is relatively expensive.

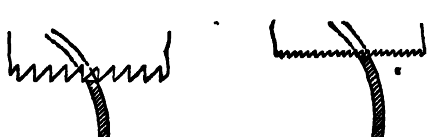
Operation. The blade must be tensioned in the frame until it gives out a musical note when plucked, the actual degree of tightness being a matter for the worker's judgment. Generally the blade is inserted with the teeth pointing forward, though there are jobs when a draw-cut will be better. As to the correct pitch of tooth for various jobs, the following can be taken as a guide:

	Teeth per in.
Mild steel of average section	14
Harder steel	18
Iron pipe, angle iron, brass, copper	22
Conduit and thin tubes	32

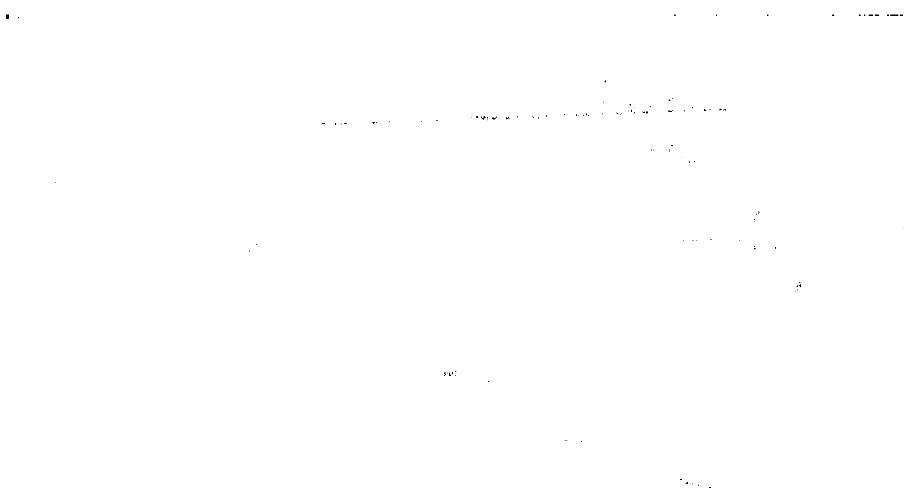
(*Abbott, Birks & Co.*)

The importance of using a fine tooth for pipes and tubes is shown by Fig. 1, where it is seen that a coarse-toothed blade catches against the edge of the work, making smooth and clean cutting impossible. A finer pitch, on the contrary, allows several teeth to rest on the work, so that they do not drop and catch on the edge.

Generally speaking, the saw should be used much as would a file, applying pressure only in the direction of the cut and letting the blade come back easily on the return. On a narrow surface the cut can be started with a notch



HACKSAW. Fig. 1. Action of coarse and fine saws on thin tubing, showing way in which coarse teeth catch edges of tube.



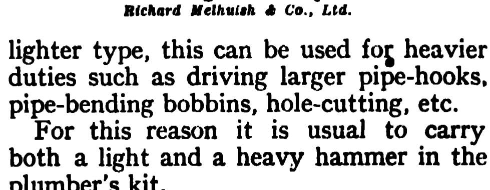
HACKSAW. Fig. 3. Hacksaw in use ; it is held firmly in both hands in horizontal position.

or nick made by a three-square file. Where practicable, as soon as the cut is well under way, give longer strokes and use the entire length of the blade. Directly any teeth are ripped out the blade ought to be discarded, as further use will break off more teeth and may damage the work. The proper way to hold and use the hacksaw is shown in Fig. 3. Blunted blades should be replaced : reliable brands are by no means expensive.

HAIR-FELT. An insulating material used for protecting water pipes from frost. It is composed of a layer of hairy felting about ⅜ in. thick, and is usually backed with a layer of ordinary coarse sacking. Hair-felt may be obtained in various widths, depending on the size of pipe it is required to cover, and is usually sold in rolls of approximately 24 ft. lineal. There are two ways of using it for lagging pipe : one is to lap it spirally round the pipe ; the other is to fold it round and sew the edges together by means of a bag needle and thin string. To make a neater job, it is advisable to turn the joint to the back of the pipe against the wall. All insulation must be kept dry.—*J. Malpass, M.R.San.I.*

HAMMER. The plumber's hammer has the pane straight (*i.e.* in line with the handle) and the usual round, flat face, with a good straight-grained ash handle shaped to be evenly balanced when in use. The early type had an extended straight pane, and varied in weight from 6 oz. to 20 oz. Advantages attributed to the design are : ability to drive copper tacks in the corners of wood cisterns, etc., when lining them with lead ; preparation of seams when making seamed lead pipes before using the gauge hook ; facility with which pipe hooks, etc., can be driven in awkward positions. Where glazing is done by plumbers, the straight pane can be used to advantage when fixing tacks in glazing rebates.

The heavier type (*see* illustration) is used in weights from 1¼ lb. to 2 lb. While possessing the advantages of the



HAMMER. Heavy type of plumber's hammer, obtainable in weights from 1¼ to 2 lbs.
Richard Melhuish & Co., Ltd.

lighter type, this can be used for heavier duties such as driving larger pipe-hooks, pipe-bending bobbins, hole-cutting, etc.

For this reason it is usual to carry both a light and a heavy hammer in the plumber's kit.

HARD WATER. Hardness in water is due to the presence of salts of lime or magnesia in the water. Rainwater as it falls is soft, but in passing through the air it absorbs carbonic acid gas, and when this water percolates through the ground or passes over rocky strata, the carbonic acid dissolves out and absorbs the salts of lime and magnesia. Water drawn from chalky strata is particularly hard.

If the salts are present in the form of carbonates the water is said to be *temporarily hard,* but if present in the form of sulphates the water is *permanently hard.* The carbonates cease to be soluble at 212° F., and are precipitated out; thus temporary hardness can be removed by boiling. Permanent hardness can be removed by caustic lime or caustic soda.

Hardness is measured in degrees, and 1 deg. of hardness equals 1 grain of bicarbonate of lime in 1 gallon of water. If the hardness is under 7 deg. the water is termed soft water; while water with more than 7 deg. is termed hard water.

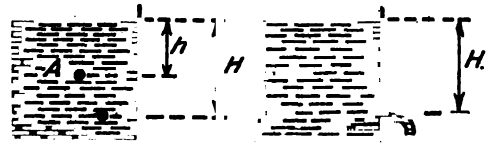
Hard waters are wasteful, as much more soap is used for washing purposes before a lather is obtained. They also cause scale to form in pipes and boilers. Soft waters have a solvent action on such metals as lead and zinc, and if passed untreated through the pipes may cause lead poisoning. For domestic purposes a water with a hardness of 6 deg. or 7 deg. is the most desirable. Hard water forms a thin coat of scale on the inside of lead or iron pipes which prevents further corrosive action from taking place.—*E. H. Vick, A.M.Inst.C.E.*

See Water; Water Softening.

HEAD OF WATER. Water at rest has a *potential energy* due to its *static head,* the height of the free surface above any point being the static head at that point.

Thus the static head at the point A (Fig. 1) equals *h* feet, and at the lower point equals H feet. The pressure increases as the depth or head increases.

Since water weighs 62·36 lb. (taken as 62·4 lb. for approximate calculations) per cu. ft., a column of water 1 ft. square and 1 ft. high will weigh 62·36 lb.; and the



HEAD OF WATER. Fig. 1 (left). Static head at two given depths marked by points. Fig. 2 (right). Kinetic energy of water expressed in terms of static head when water is flowing from tank and head H is constant (see text).

pressure exerted on the base will be 62·36 lb. per sq. ft., or 0·433 lb. per sq. in.

The pressure in lb. per sq. ft. due to any head of liquid is given by the formula:

$p = wh$ where w equals the weight in lb. of 1 cu. ft. of the liquid and h is static head in ft.

This pressure will be equal in all directions at this point.

Water in motion possesses *kinetic energy* which may be expressed in terms of static head. Fig. 2 represents water flowing from a tank in which the head H is kept constant, the water having a velocity of V ft. per sec. A small particle of water at the free surface will have a weight W and a potential energy of WH. When this particle of water issues from the outlet with a velocity of V ft. per sec., it will have fallen through a height H and its potential energy will have been converted to kinetic energy.

$$WH = \frac{WV^2}{2g}$$

$$\therefore \quad H = \frac{V^2}{2g} \text{ or } V = \sqrt{2gh}$$

V is the actual velocity of the water after falling through a height H (neglecting all friction losses).—*E. H. Vick, A.M.Inst.C.E.*

See Hydraulics.

HEAT: GENERAL THEORY FOR STUDENTS

By Norman Wignall, A.M.I.Mech.E., M.I.H.V.E.

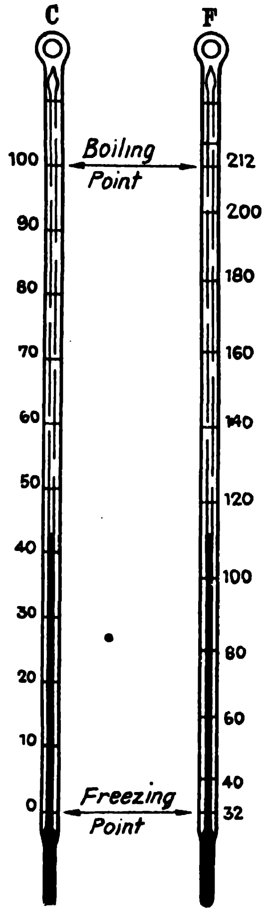
A clear and simple explanation of the theory, with special reference to the work of the Plumber, Heating and Ventilating Engineer. See Heating: (1) Theory; Hot Water; Temperature; Thermometer.

Heat is a form of energy possessed by a body, due to the state of motion of the molecules of which the body is composed. In solids the molecules remain stationary, but are in a state of vibration which is increased by the addition of heat. In the case of liquids the motion of the molecules is not only increased but at the same time currents of molecules may be caused to travel from one part of the liquid to another. In gases the molecules are in rapid motion, and collisions with each other and the walls of the vessel containing the gas are frequent, the continual bombardment resulting in pressure raised within the vessel. Heat energy may be converted into work, and vice versa; Joule's experiments showed that 1 B.Th.U. was equivalent to 772 foot-lb. of mechanical work.

All heat is obtained from natural sources, or produced by methods which

depend upon natural stores of heat energy. Thus the most obvious natural source is the sun, the rays from which are being utilized to a slight extent in tropical climates for the production of mechanical work.

Volcanic heat is also being used for power production. The principal commercial sources of heat, however, are fuels, a fuel being any substance capable of chemical combination with the oxygen in the atmosphere resulting in the evolution of heat and light (*i.e.* in combustion).



HEAT. Centigrade and Fahrenheit mercury thermometers. Formulae for converting readings are given under Centigrade, p. 220.

Temperature. This is degree of hotness; it may be measured by a thermometer (*which see*), which utilizes the expansion of mercury or alcohol (taking place on rise of temperature), causing a thread of the liquid to rise or fall in a fine-bore glass tube on which fixed points are marked, representing the freezing point and boiling point of water, at atmospheric pressure. Between these points the thermometer is divided into a number of degrees.

Quantity of Heat. Thermometers measure temperature only, but not quantity of heat, which depends on other factors, of which temperature is only one. The Fahrenheit unit of heat is the *British Thermal Unit* (B.Th.U.), which is

the quantity of heat required to raise 1 lb. of water through 1° F.

This forms the basis of all heating calculations. Thus, if 10 lb. of water be raised through 50° F., the heat required will be 10 × 50 = 500 B.Th.U.

Specific Heat. This is the amount of heat required to raise unit mass of any substance through 1° F. The specific heat of water is taken as unity, as 1 B.Th.U. will raise 1 lb. of water 1° F. The specific heats of other substances are expressed as a fraction, as shown in Table 1:

TABLE I.
Specific Heats at Ordinary Temperatures

Element	Specific Heat
Water	1·0000
Air	·24
Mild steel	·1158
Cast-iron	·1216–·1298
Copper	·0965
Tin	·0562
Brass	·0940
Lead	·0314
Aluminium	·2143
Silver	·057
Zinc	·0956
Gunmetal	·0952
Asbestos	·20
Firebrick	·20
Glass	·16
Rubber	·37
Ice	·50

Engineer's Year Book

Thus, if it is required to add to or take from the heat content of anything, the heat quantity can be obtained from:

Mass (in lb.) × (Temperature gain or loss) × (Specific Heat).

The specific heat varies with temperature, but the variation is practically negligible between the limits used in heating and ventilation.

Expansion Due to Heat. If heat be applied to a solid, temperature is raised and expansion takes place.

The *coefficient of linear expansion* of a substance is

the increase in length which a bar of unit length undergoes when its temperature is raised through one degree.

If a = the coefficient of linear expansion,
L = original length of bar,
t = rise in temperature;
Then increase in a bar of unit length = $a\,t$;
" " " " length L = L $a\,t$.
Final length of bar = L + L $a\,t$ = L $(1 + a\,t)$.

Table II (p. 494) shows the coefficients of linear expansion of various substances.

The *coefficient of superficial expansion* is the increase in area which a plate of unit area undergoes when its temperature is raised through one degree. For all practical purposes it is twice the coefficient of linear expansion for the same substance.

The *coefficient of cubical expansion* applies to unit volume in the same way,

TABLE II.

Coefficient of Linear Expansion of Various Substances per Degree F. (Ordinary Temperatures)

Substance	Coefficient of exp.
Wrought-iron	·00000656
Cast-iron	·00000618
Lead	·00001581
Copper	·00000922
Firebrick	·00000275
Brass	·00001075
Aluminium	·0000245
Nickel	·0000128
Tin	·0000223
Zinc	·0000292
Steel	·0000069
Glass	·0000048
Red Brick	·0000030
Marble	·0000061
Granite	·0000044

Compare Table in p. 371 (Deg C).

and is three times the coefficient of linear expansion for the same substance.

During expansion, the weight remains constant but volume increases. Therefore density (mass per unit volume) diminishes.

Effect of Heat on Water and Ice. If heat is taken from water, temperature falls until it eventually solidifies into ice at 32° F. or 0° C. When water is cooled, contraction takes place until a temperature of 39° F. (4° C.) is reached, but further cooling is accompanied by expansion. The maximum density of water is attained at this temperature (which explains why ice forms on the surface).

When water turns to ice, expansion is considerable, 11 cu. in. of water forming approximately 12 cu. in. of ice. This is most important from the plumber and heating engineer's view-point, since it is the cause of water pipes bursting during severe frost. The expansion during freezing does the damage, which does not show until the ice thaws.

When heat is abstracted from water at freezing point the temperature remains constant until all the water is turned to ice. The heat thus abstracted at constant temperature is the *latent heat of fusion*, or

the quantity of heat necessary to change unit mass from liquid to solid (or vice versa).

The latent heat of fusion of ice is 144 B.Th.U. per lb., which means that this quantity of heat must be applied to change 1 lb. of ice into water at 32° F.

Heat applied to water (above 39° F.) causes temperature to rise and expansion to take place. The expansion is approximateiy 1/23 of its bulk during a rise in temperature of 30° F. to 212° F. (boiling point). At this point if heat continues to be applied, the temperature remains constant until all the water is vaporized into steam. Thus the boiling point at atmospheric pressure is 212° F., and to change 1 lb. of water into 1 lb. of steam at this temperature requires 970 B.Th.U. This is known as the *latent heat of evaporation*, or

the quantity of heat which must be imparted to unit mass in order to effect the change from liquid to gaseous at constant temperature.

To a heating engineer this is most important, since in all steam heating it is the latent heat of the steam which is actually used.

Latent heat varies with pressure, as also does boiling point, and as the pressure is increased, the boiling point also increases, but latent heat decreases.

Total heat is the latent heat at a given pressure plus the heat required to raise the water to the boiling point corresponding to that pressure from 32° F.

In other words it is the total heat required to raise the temperature of the water to boiling point (termed "sensible heat" where it is accompanied by a temperature difference), plus the latent heat of evaporation at the pressure under consideration. Although latent heat decreases with rise in pressure, total heat increases continuously with pressure, since more sensible heat is required to raise the water to boiling point at higher pressures.

Heat Transfer. Heat may be transferred from one point to another by three methods, as follows:

(1) *Radiation.* Where transmission takes place from one body to another through a vacuum or through an intervening medium without affecting the temperature of the medium. The laws governing the transmission of heat by radiation are similar to those of light.

(2) *Conduction.* Where heat transfer is affected by the transfer of heat from one particle to another in any substance. Thus heat is passed through a body from a hot part to a cooler part without alteration in the relative positions of the parts of the body.

The *coefficient of conduction* is the quantity of heat transmitted through 1 sq. ft. per hour per degree difference in temperature between the outside faces of any body or material per inch thickness.

(3) *Convection.* Where heat is transmitted through the body of a substance by means of the motion of heated particles from one point of the body to another. This type of heat transmission can only occur with liquids or gases, where the currents of either so set up are termed "convection currents."

HEATING: (1) THE MODERN THEORY

By W. E. Fretwell, F.R.San.I., P.P.I.H.V.E., M.I.Mech.E.

The basic principles of heating, the applications of which are dealt with in later articles of this Group. A Colour Plate is included. The group of articles on Heat and Heating is arranged thus:

Associated articles of importance which must be consulted include Boiler; Calorifier; Gas Fires, etc.; Hot Water Supply; Pipe Sizing: (1); Radiant Heating: (1) & (2); Radiator, etc. Special heating schemes are given under the headings Factory; Flat; Hospital; Hotel; Schools, etc.

To understand the theory of heating requires an intimate knowledge of certain technical terms, the principles of heat transmission and the fundamental laws controlling the flow of fluids. (For these the reader should refer to the headings Heat; Hot Water.) The practice of heating is the application of these principles to the problems on hand.

The approximate amount of heat dissipated by an adult wearing normal indoor clothing in surroundings at 60° F. is:

Moderate hard work ..	436	B.Th.U. per hour
Moderate sedentary work	333	" "
Absolute rest	215	" "

Comfort Conditions. Human beings and animals produce internal heat energy through the chemical and physical process of the digestive combustion of foodstuffs. The heat energy produced is used up mainly by radiation, convection and evaporation. For a healthy person the interior heat production and heat losses must balance. A too rapid loss of bodily heat is injurious; conversely, loss of heat must not be unduly hampered or discomfort, fainting, and ill-health will result.

Ignoring special thermal and other conditions required for certain industrial and process work, the primary function of a "heating" or "warming" installation is to produce an environment ensuring a steady and comfortable loss of heat from the body, and not, as so often stated, to warm the occupants. Such an environment may be provided by (1) convection system; (2) "radiant" heating system; or (3) a combination of both systems.

1. **Convection Heating Systems.** Those whereby the space is filled with warmed air: *e.g.* (*a*) a system by which rooms are indirectly warmed through the medium of a warm air heater installed in a basement, heater room or other position; (*b*) a unit heater system; (*c*) the warming of rooms by pipe coils or radiators of the column type is mainly by convection.

There should be present in every room an adequate supply of relatively cool moving air for respiration and other purposes, and to evaporate skin moisture and carry away exhaled and other polluted air.

2. **'Radiant' Heating Systems.** Systems whereby radiant energy from warmed surfaces is caused to impinge on the body, the room enclosing surfaces and its contained objects: *e.g.* a room warmed by steam or hot water heated "radiant" warming plates or panels; luminous and incandescent electric and gas heaters; open fires and the like. Radiant energy, by warming the room and other surfaces, transmits heat to the air in contact therewith and sets up convection currents; such currents, however, are usually of a lesser amount than for other forms of heating.

Heat Loss Calculations. For all forms of heating the general practice is

to estimate the quantity of heat required to warm a room or other space by first computing by the aid of heat loss coefficients (*see* Heat Loss) the quantity of heat transmitted through and lost or gained from the room-enclosing materials, to which must be added that required to warm the ventilating air. The cubic capacity of the room, multiplied by the air interchange figure, gives the quantity of air to be warmed. Temperature of entering air and external air is presumed to be the same. Internal and external surfaces of the room-enclosing materials are presumed to be at room temperature and external temperature respectively. Neither of these assumptions is correct.

Air Interchange. The amount of air escaping from any room or the like cannot be accurately predetermined, depending as it does upon differential air pressures, ill-fitting doors and windows, porosity of building materials, opening of doors and windows, and other varying factors.

Some heating engineers measure the lineal feet of "crack" around external windows and doors and employ a constant from which the air to be warmed is calculated. Specifications for heating should always state the air interchange to be provided.

'Steady-State' Temperature Condition. This implies that the room has already attained the specified temperature and that the subsequent amount of heat supplied to the room synchronizes with that escaping from it, the internal and external temperature conditions remaining constant at the temperatures specified.

Orientation. For surfaces having a north or east exposure, increase the "steady-state" heat loss calculations by about 10 per cent. Some 10 per cent. should also be added where strong winds prevail.

Warming-up Period. This is the length of time the apparatus takes to warm up the building and to reach "steady-state" temperature conditions. It depends upon the thermal condition of the building; a new building constructed of heavy material may take several months to dry out (about 1,000 B.Th.U. being required to evaporate 1 lb. of water). The heavier the building the more heat will be required to warm the structure and the longer it will take to cool down: on the other hand an empty corrugated iron building has but little thermal capacity.

Churches and other buildings used for short periods in winter seldom reach a steady temperature condition, and ample heating surface should be provided accordingly. An addition of up to, say, one-third of the "steady-state" heat transmission calculations should be provided in extreme cases. For intermittent operation of, say, 9 to 12 hours per day, an addition of about 20 per cent. to the heat required to maintain a "steady-state" condition should be made.

Heating Surface Required. The amount of heat emitted by any heating element is the sum of its radiation and convection losses, direct or indirect.

To maintain "steady-state" temperature conditions, the amount of heat per hour to be provided for a given room is the same as the heat losses therefrom.

The amount of heating surface required depends upon its type, surface temperature, decoration, location, and whether or not it is encased. In certain cases regard should be had to heat introduced by occupants and from other sources, such as heat gains from adjoining spaces, lighting, mechanically driven appliances, etc.

When designing hot water and steam heating installations the heating engineer usually estimates the amount of heating surface to be provided by dividing the hourly B.Th.U. losses by the average heat transmission per sq. ft. of heating surface installed.

For rooms heated by electrical devices the amount of heat introduced is obtained by multiplying the number of Board of Trade Units by 3,415, the latter being the B.Th.U. equivalent of one kWh.

Where gas, oil and other fuels are consumed within the room the heat output therefrom is obtained by multiplying the calorific value unit by the quantity consumed. The proportion of such heat usefully employed to warm the room varies, of course, with the type of apparatus installed.

The employment of coefficients for heat losses through materials is not necessarily an accurate calculation of what actually occurs. For example, in practice heat loss calculations are usually prepared from architects' plans, and the heating engineer cannot be expected to know the exact

thermal conductivity of bricks and other structural materials to be used, the quality of workmanship employed in putting them together, and the manner in which the internal and/or external surfaces are to be treated, if at all. Nor is it possible to estimate the quantity of air interchange. The probable air velocity over the external walls and other surfaces is also a matter of guesswork. For examples of heat loss calculations *see* Heat Loss.

Principles of Fluid Circulation. Gravity circulation is set up by the warming of fluid particles which immediately expand and become buoyant; in consequence of this they ascend and carry heat with them, their place being taken by cooler and heavier particles. Actually it is the latter which force warmer particles to ascend. For any given gravity circulating circuit the sum of the heights of the ascending and descending columns is the same.

The product of the sum of the fluid density (weight in lb. per cu. ft.) and height of each vertical section of the descending column over that of the ascending column is an actual measure of the force in lb. per sq. ft. producing circulation. The imaginary system shown by Fig. 1 (in Plate facing page 496) will serve to explain the theory of circulation.

The excess pressure exerted by the descending over the ascending column is 1588·239−1578·012=10·227, and represents for Fig. 1 the circulating pressure in lb. per sq. ft.

TABLE No. II. Value of Ascending and Descending columns for System in Fig. 1 (*see* Plate *facing page* 496)

Ascending Column				
1 Section	2 Temp. °F.	3 Height	4 Density lb. per cu. ft.	5 Product of Col. 3 & Col. 4
A.1	140	2′ 0″	61·388	122·776
A.2	160	2′ 0″	60·998	121·996
A.3	180	2′ 0″	60·560	121·120
A.4	178	20′ 0″	60·606	1212·120
		26′ 0″		1578·012
Descending Column				
1 Section	2 Temp. °F.	3 Height	4 Density lb. per cu. ft.	5 Product of Col. 3 & Col. 4
D.1	177	1′ 0″	60·630	60·630
D.2	176	5′ 0″	60·652	303·260
D.3	160	2′ 0″	60·998	121·996
D.4	159	5′ 0″	61·018	305·090
D.5	150	2′ 0″	61·201	122·402
D.6	142	11′ 0″	61·351	674·861
		26′ 0″		1588·239

In practice, circulating pressures are now generally expressed in inches of water at 62° F., which temperature corresponds with the British Standard Temperature for specific gravity. The density of water at this temperature is 62·360 lb. per cu. ft. With water at this density the height of water column corresponding to a pressure of 1 lb. per sq. ft. is $\frac{12}{62 \cdot 360} = 0 \cdot 19243$, or, say, 0·192 in. high. For Fig. 1 in the Plate the equivalent

TABLE No. I (*see* page 498)

Circulating Pressure in inches of Water Column at 62° F. for a Height (h) of 1 ft.

By W. E. Fretwell, P.F.H.V.E.

Flow Temp. °F.	Return Temperature (Degrees Fahr.)														
	180	175	170	165	160	155	150	145	140	135	130	125	120	115	110
200	·088	·108	·129	·148	·167	·188	·205	·223	[illegible]	·257	·275	·290	·305	·319	·332
195	·057	·076	·108	·127	·146	·167	·184	·202	·219	·236	·253	·269	·284	·298	·311
190	·040	·063	[illegible]	·100	·123	·144	·161	·179	·196	·203	·230	·246	·261	·275	·288
185	·023	·042	·063	·083	·102	·123	·140	·157	·175	·192	·209	·225	·230	·253	·267
180	—	·019	·040	·060	·079	·100	·117	·134	·152	·169	·186	·202	·211	·230	·244
175	—	—	·021	·040	·060	·080	·098	·115	·132	[illegible]	·168	·182	·190	·211	·225
170	—	—	—	·019	·038	[illegible]	·077	·094	·111	[illegible]	·146	·151	·173	·190	·204
165	—	—	—	—	·023	·042	·056	·077	·092	·111	·129	·144	·152	·173	·186
160	—	—	—	—	—	·021	·035	·056	·072	·090	·108	·123	·131	·152	·165
155	—	—	—	—	—	—	·017	·035	·052	·070	·088	·102	·113	·131	·144
150	—	—	—	—	—	—	—	·017	·035	·052	·069	·084	·096	·113	·127
145	—	—	—	—	—	—	—	—	·017	·035	·052	·068	·079	·096	·109
140	—	—	—	—	—	—	—	—	—	·017	·035	·050	·061	·078	·092
135	—	—	—	—	—	—	—	—	—	—	·017	·032	·044	·061	·075
130	—	—	—	—	—	—	—	—	—	—	—	·015	·029	·044	·058
125	—	—	—	—	—	—	—	—	—	—	—	—	·015	·029	·042
120	—	—	—	—	—	—	—	—	—	—	—	—	—	·013	·028
115	—	—	—	—	—	—	—	—	—	—	—	—	—	—	[illegible]

circulating pressure in inches of water column at 62° F., is $10{\cdot}227 \times 0{\cdot}192 = 1{\cdot}964$ in., and this also represents the total resistance to flow of water through the system.

Table I (in p. 497), calculated by the writer, gives the value of the circulating pressure, in inches of water column at 62° F., for a height of one foot of ascending and descending column. The terms "ascending" and "descending" columns are used in place of "flow" and "return," the reason for this being that the direction of the water flowing through these columns may be either up or down. Some engineers base the circulating pressure on the mean density between ascending and descending water columns. No fault is to be found with this method, which is used by Mr. Overton in his article on Heating: (2) in this work (pages 499 to 510). Calculation of the resistance to flow of water through the pipes (or other parts of the system) must, however, be based on one or other of these methods.

Pipe Sizing Hot Water Gravity Systems. All gravity hot water systems are "pipe sized" for "steady state" operating conditions during which flow and return temperatures are presumed to remain constant; the heat supply then balances that "lost" from the apparatus.

Physical forces ordain that during circulation the circulating pressure for each circuit and resistance to flow of water through it have precisely the same numerical value. Pipe sizing calculations involve:

1. A decision as to the average difference in temperature to be maintained between ascending and descending columns.
2. The circulating pressure available.
3. The weight of water to be circulated.
4. The selection of pipe diameters. Ensuring that the total resistance to flow is within the available circulating pressure.

(*See further under Pipe Sizing.*)

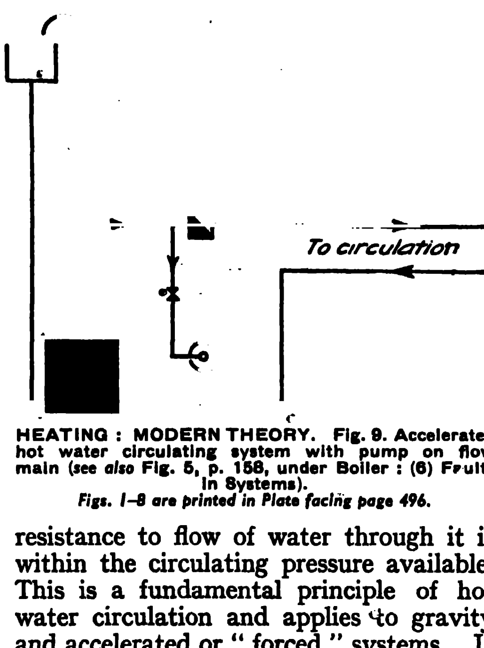
Fig. 2 (*see* Plate *f.p.* 496) will further serve to explain that for every circuit the force producing circulation (circulating pressure) and the resistance to flow of water through it are identical. Circulation through the ascending and descending columns is presumed to be uniform at a mean water temperature of 180° and 140° F. respectively. For these conditions the circulating pressure, in inches of water column at 62° F., for each circuit is obtained by multiplying the height of the circuit (measured as shown) by $0{\cdot}152$. (*See* Table I. in p. 497.)

Radiator A. The "index radiator" is 5 ft. above the boiler and its circulating pressure is $5 \times 0{\cdot}152 = 0{\cdot}76$ in. of water column. Its circuit comprises the boiler, pipes 1, 1a, 2, 2a, 3, 3a, and the radiator itself.

Radiator B is also 5 ft. above the boiler and its circulating pressure is the same as for Radiator A, or 0·76 in. of water column. Its circuit comprises the boiler, pipes 1, 1a, 2, 2a, 4, 4a, and the radiator itself. It is interesting to note that the resistance to flow of water through pipes 4 and 4a is identical with that through pipes 3 and 3a, serving Radiator A.

Radiator C is 15 ft. above the boiler and its circulating pressure is $15 \times 0{\cdot}152 = 2{\cdot}28$ in. of water column. Its circuit comprises the boiler, pipes 1, 1a, 5, 5a, and the radiator itself.

For each circuit the calculated diameter of pipes, when carrying the required weight of water, should be such that the



HEATING: MODERN THEORY. Fig. 9. Accelerated hot water circulating system with pump on flow main (*see also* Fig. 5, p. 158, under Boiler: (6) Faults in Systems).
Figs. 1–8 are printed in Plate facing page 496.

resistance to flow of water through it is within the circulating pressure available. This is a fundamental principle of hot water circulation and applies to gravity and accelerated or "forced" systems. If care is taken to comply with these basic principles, "short-circuiting" is impossible.

When designing hot water gravity systems it should be borne in mind that, wherever practicable, it is always an advantage to install a "drop" system—*i.e.* a system in which the flow main is carried along above the radiators, which are then served by descending water columns. By so doing, the maximum circulating pressure is obtained.

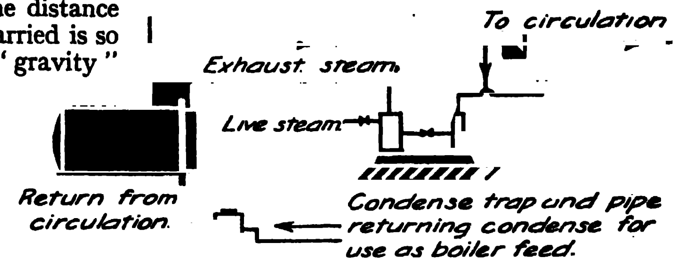
Figs. 3 to 8 (*See plate f. p.* 496) show various circulating systems.

The method of calculating pipe sizes is dealt with by Mr. Overton in Heating: (2) *and in* Pipe Sizing.

Accelerated or Forced Hot Water Circulating Systems. These are commonly employed where the distance that hot water has to be carried is so great as to necessitate "gravity" mains of excessive diameter, and are also installed to overcome difficulties in levels. Now that electricity is so generally available the usual method is to produce circulation by installing an electrically driven centrifugal pump. The engineer must decide the head of water (circulating pressure) and the quantity of water to be circulated, and this information must be passed on to the pump manufacturer.

Except that circulation is produced by mechanical means, the calculations involved in designing an accelerated system are similar to those employed for a gravity circulation (*see* Figs. 9 and 10).

Where a supply of high-pressure steam is available, a turbine driven pump may be installed in lieu of an electrically driven pump set. In this case the steam exhausted by the turbine is often employed to warm the circulated water by means of a calorifier (*see* Fig. 10). The condensate should be "trapped" and returned for use as boiler make-up water.



HEATING: MODERN THEORY. Fig. 10. Turbine driven accelerated hot water heating system using exhaust from turbine in calorifier to warm circulated water.

Steam Heated Systems. The general physical principles of heating apply to both steam and hot water systems. The principal difference between these systems is that whereas a gravity hot water system obtains its motive force by the excess pressure exerted by descending columns, a flow of steam is due to a drop in pressure, following condensation of steam, as it flows through the mains, branches and radiators or other heat-transmitting element.

HEATING: (2) CENTRAL HEATING BY HOT WATER

By Louis J. Overton, M.I.H.V.E.

The theory of Heating having been set out in the first article of this Group, the present article is devoted to heating by hot water Sections are: A, Circulation; B, Apparatus; C, Design of a Scheme; D, Heat Requirements; E, Selection of a Scheme; F, Choice and Use of Fuel; G, Temperature Guarantee and Testing; H, Cost Considerations; J, Structural Requirements. *See* Chart *facing page* 504.

The term "central heating by hot water" may be applied to all systems where the warming of buildings is accomplished by heating water in a boiler, furnace coil or calorifier at one point of a building, and the water so heated is circulated through pipes to pipe coils or radiators in other parts of the building, the pipes and radiators transmitting heat to rooms away from the point where the heat is generated. Thus, all the rooms in a building, or even in several buildings, may be warmed from one central plant house or boiler room.

Heating the Water. There are numerous types of boilers in which water may be warmed for a central heating system. These are described under the heading Boilers: (1) and (7) (*see* pages 131 and 160). Various kinds of fuel may be used, such as coal, coke or anthracite; and boilers can be manufactured or adapted for oil firing or gas firing.

Water for central heating can be warmed in calorifiers (*which see*) by the use of steam transmitting heat from a pipe coil or inner cylinder to the water. Water for this purpose can also be warmed in a cylinder by means of an immersed electric element; this is the method used when a thermal storage system (*which see*) is adopted in order to take advantage of a cheap rate at which electric current is supplied during certain hours of light

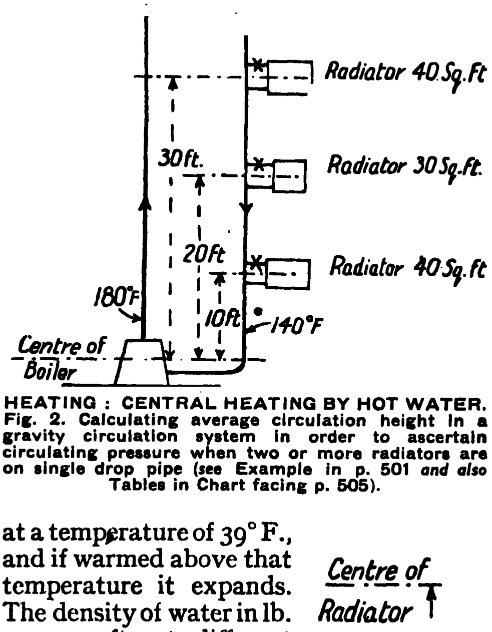
duty (which occur between about 11 p.m. and 7 a.m. at the power station).

A. CIRCULATION OF THE WATER

The circulation of the water in a central heating system may be by convection, due to the natural force of gravity; or it may be mechanical, by means of a pump. Circulating pumps may be driven by electric motor, steam, oil or petrol engines, or any other motive power; but as electric current is now available in most districts, an electric circulating pump is generally used.

Gravity Circulation System. The circulation of hot water by gravity in a central heating system is due to the difference in density between two columns of water—one column being the hot rising flow pipe from the top of the boiler and the other the dropping return pipe to the bottom of the boiler.

Water is at its greatest density when



HEATING: CENTRAL HEATING BY HOT WATER. Fig. 2. Calculating average circulation height in a gravity circulation system in order to ascertain circulating pressure when two or more radiators are on single drop pipe (see Example in p. 501 and also Tables in Chart facing p. 505).

at a temperature of 39° F., and if warmed above that temperature it expands. The density of water in lb. per cu. ft. at different temperatures is given in Table I in Chart.

The force by which gravity will cause the circulation of water in a heating apparatus depends upon the difference in temperature between the rising hot water column and the cooler dropping column, and the greater the temperature difference the greater will be the circulating force. This circulating force is also increased in direct proportion to the height of the two columns. If the columns of water in a circulation with a definite temperature difference are increased to three times the height, the circulating force also will be increased three times.

Example. Assume a radiator is placed on a circulation at a height of 10 ft. above the centre line of a boiler, as shown by Fig. 1. The rising flow is 180° F. and the dropping return 140° F. Should the temperature in the dropping return pipe be 160° F. instead of 140° F., the circulation force would be reduced, due to the return water being lighter; and if the height from the centre of the boiler to the radiator is increased from 10 to 30 ft. the circulating force will be trebled.

The distance at which the radiator is placed above the boiler is termed its circulation height, and the force of gravity available for causing a circulation is termed the circulating pressure.

Circulating Pressure. This is generally expressed in ins. water gauge (or head pressure), and may be calculated with the density table and the following formula:

$$\frac{D^1 - D^2}{\frac{D^1 + D^2}{2}} \times 12 = X$$

Where D^1 = Return density.
„ D^2 = Flow density.
„ X = Circulating pressure in inches per foot of circulation height.

Example. Calculate the circulating pressure available for the radiator as illustrated by Fig. 1.

Referring to Table I, it will be seen that:
The return density D^1 at 140° F. is 61·388.
„ flow „ D^2 at 180° F., is 60·560.

Then:

$$\frac{61{\cdot}388 - 60{\cdot}560}{\frac{61{\cdot}388 + 60{\cdot}560}{2}} \times 12 = X$$

$$\frac{{\cdot}828}{60{\cdot}974} : 12 = {\cdot}163 \text{ in. per ft. of circulation height.}$$

·163 × 10 ft. = 1·63 in. total circulating pressure.

This means that the force of gravity is equivalent to a head of water 1·63 in. high.

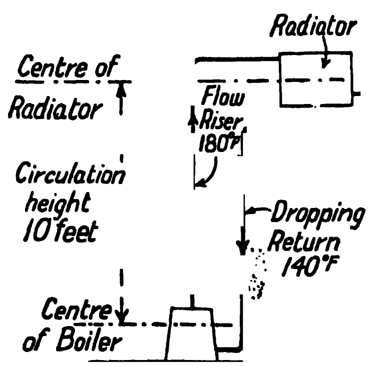


Fig. 1. Factors controlling circulating pressure in gravity circulation system: circulation height of 10 ft.; flow riser at 180° F., and return drop at 140° F. (for calculations, see Example above).

For easy reference the circulating pressure per foot of circulation height may be read direct from Table II (*see* Chart *f.p.* 505), which includes the range of temperatures that might be used in calculations for a gravity central heating system.

When two or more radiators are placed on a single-pipe drop system at different levels an average circulation height is used for calculating the circulating pressure.

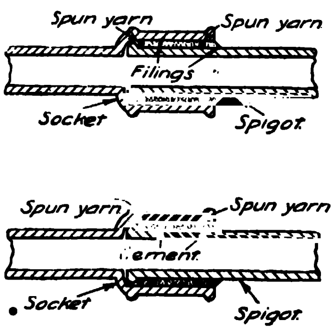
Example. Assume a gravity circulation on a single-pipe system serves one radiator of 40 sq. ft. at 10 ft. above the boiler, one radiator of 30 sq. ft. at 20 ft. above the boiler, and one radiator 40 sq. ft. at 30 ft. above the boiler, as illustrated by Fig. 2. The average circulation height can be arrived at in the following manner:

Radiator		
40 sq. ft.	× 30 ft. height above boiler	= 1,200
30 „	× 20 „ „ „ „	= 600
40 „	× 10 „ „ „ „	= 400
110		2,200

$\frac{2,200}{110}$ = 20 ft. average circulation height.

These calculations of gravity force form the basis on which correct pipe sizes are determined for gravity circulation systems (Fig. 1).

When designing a gravity system it should always be borne in mind that water cooled in a rising pipe retards the circulation, while water cooled in a return pipe sloping downwards or dropping assists the circulation. Dips in a pipe retard the circulation, but if they have to be introduced they do not check the circulation much if they are well covered with insulation to keep the water from cooling in the dipped pipe.



HEATING. CENTRAL HEATING BY HOT WATER. Figs. 3 and 3A. Caulked socket and spigot joints for cast-iron circulating pipes: (above) "rust" joint made with spun yarn and iron filings; (below) joint made with spun yarn and cement avoid dangers of rust joint.

Care should be taken to grade the level of pipes and make connexions to radiators in such a manner that the air will be automatically released, but where this is impracticable air taps should be fitted.

Heat Emission to the Rooms of a Building. In a central heating system the hot water circulated in pipes to the rooms of a building gives off heat by radiation and convection from pipes and radiators which may be placed in the rooms.

The capacity of water to absorb heat in the boiler and emit heat to the room is measured in British Thermal Units on the basis that in the boiler each lb. of water raised 1° F. absorbs one B.Th.U., and in the circulating pipes and radiators each lb. of water cooling 1° F. emits 1 B.Th.U.

B. TYPES OF APPARATUS USED

Practically all the types of material ever used for warming water, circulating it, and emitting heat from it to rooms still exist, and may be observed in one building or another in every district. The oldest method, consisting of brick-set wrought saddle or Cornish Trentham boilers, with circulations and coils of cast-iron socket and spigot pipes, is still used in horticultural buildings and in many public buildings, schools and churches. The pipes are cast to standard nominal bores, 2 in., 3 in., 4 in. and 6 in. diameter, the 2-in. pipes being in 6-ft. lengths and the 3, 4 and 6-in. pipes being in 9-ft. lengths.

Joints of these pipes are made with spun yarn and iron filings, mixed with a solution of sal ammoniac and water. When the spigot end of a pipe has been inserted into the socket end of another pipe for continuation, a ring of spun yarn is inserted, after which iron filings mixed with the sal ammoniac solution are packed in, then another ring of spun yarn inserted, and as a finish, more filings are caulked in and smoothed off (*see* Fig. 3). Such joints rust up solid and become actually the strongest portions of the piping. Should a very strong solution of sal ammoniac be used, however, the rusting process becomes too drastic and pipe sockets are liable to burst through excessive corrosion.

The London County Council took exception to rust joints on this account and resolved that all caulked joints of cast-iron pipes should be made with spun yarn and Portland cement. To make such joints first insert a ring of spun yarn, then cement, and another ring of spun yarn, finished off smooth with cement (*see* Fig. 3A).

Heat is emitted to the building by pipes ranged round the rooms, pipes in trenches with cast-iron gratings over them, and coils of piping with box ends. These last named are very unsightly and therefore are usually encased in with ornamental gratings and covers.

For general schemes of central heating by hot water the boilers are now mostly

of sectional type, and cast-iron pipes have been almost entirely superseded by wrought piping and radiators. These are much neater in appearance, and the radiators may be obtained in such a variety of shapes and sizes that almost any decorative scheme can be worked to; or by using radiator panels which are fixed flush with the wall or ceiling surface, an invisible method of heating is obtained.

C. DESIGN OF A HEATING SCHEME

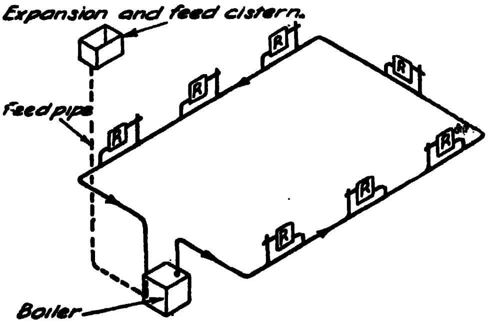
The design of a scheme must be carried out to suit the particular planning of the building which has to be dealt with, and calls for perception and skill on the part of the engineer. If a set of plans for a building were handed to several expert heating engineers to design a scheme there is every possibility that the proposed schemes would differ in many details.

The main points to keep in view are that the most simple and shortest route for pipes when serving a radiator is the best, and that complicated cross connexions of pipe circulations are, above all, to be avoided.

If the scheme is to work by gravity, it should be borne in mind that the water cooling in pipes or radiators should be disposed in such manner that its increase in density helps the circulation; and as far as possible the piping should be arranged so that air can escape freely and naturally. Water contains air in suspension and gives it off after stagnation, and an accumulation of air in any part of the system may cause water-hammer, or even completely hold up the circulation.

There are several recognized designs for systems, which will be illustrated by diagrams (*see also* Plate *f.p.* 496).

Single-pipe Ring Main System. (Fig. 4.) In this there is only a single pipe



HEATING: CENTRAL HEATING BY HOT WATER
Fig. 4. Single-pipe ring main system in which rising pipe connexions are taken to radiators from single pipe of uniform diameter running around building.

of uniform diameter carried around the building, either above or under the floor as found suitable; and from this pipe circulation rising pipe connexions are taken straight to radiators which are placed above the circulation.

The branch flow connexion to a radiator should enter it at the top; the return connexion should be from the bottom of the radiator at the opposite end to the flow, and this connexion returns direct to the single-pipe circulation.

Although this is a very simple direct scheme, and serves very well for a large one-room building, it would not be so suitable for a building divided up into rooms, as the water cooled in each radiator returns and mingles with the

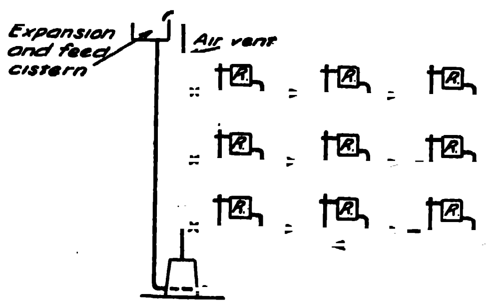


Fig. 5. Single-pipe loop system in which independent loop circulations serve each floor, and radiator connexions are the same as for Fig. 4.

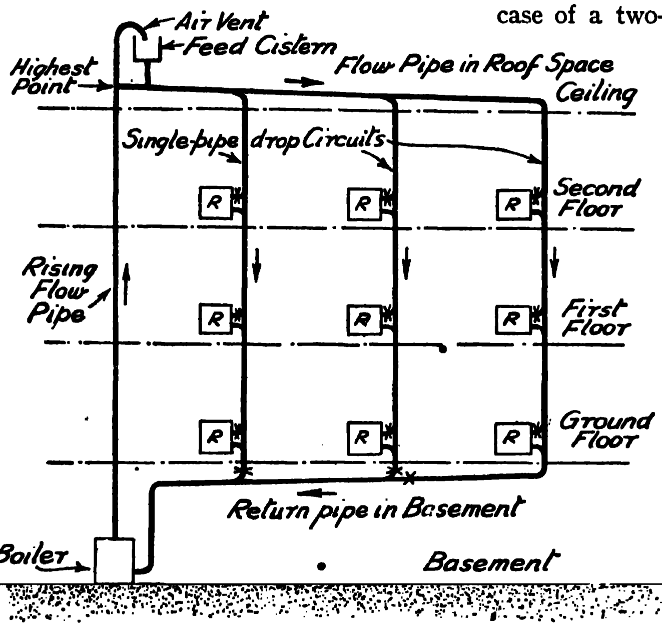
water in the main, reducing the temperature; and so the last radiator on the circulation must inevitably be much cooler than the first radiator.

Single-pipe Loop System. (Fig. 5.) In this system a main riser is taken from the boiler with loop circulations along the various floors of the building, joining into a dropping main return pipe to the boiler. Each loop circulation can be valved so that any section can be regulated or shut off as desired. The connexions to radiators are similar to those described for a ring main system.

Single-pipe Dropping System. (Fig. 6.) This system is often found very suitable for private houses and some types of building where the main flow pipe can rise direct to the roof space, and flow in the roof space with a slight slope downwards, branching into several dropping pipes in convenient corners of the building, each drop feeding radiators on the various floors. The dropping pipes are collected into a main return, which can be carried below the floor, back to the

boiler. With this system the radiators, if placed near the dropping pipe, can be served with top and bottom connexions at the same end, as shown in Fig. 6.

It is a fact that in this scheme the cooling of the water in the flow pipe placed in the roof space and the cooling of the water in the dropping pipes to radiators at the higher level actually help to quicken the circulation, but this cooling effect must not be allowed to exceed a certain limit



HEATING: CENTRAL HEATING BY HOT WATER. Fig. 6. Single-pipe dropping system: main flow slopes gently downwards from high point and is branched to single drop pipes serving radiators; drop pipes are collected into main return (see also Figs. 10 and 11 in Chart facing p. 50)

or the radiators on the lower floor will be too cool for effectively warming the rooms on that floor.

Two-pipe System. (Fig. 7.) A two-pipe system has a very distinct advantage over a single-pipe system, as all the water which circulates through each radiator returns direct into a main return pipe back to the boiler; therefore the water in the flow piping, even to the radiator farthest from the boiler, is never cooled by water from another radiator mingling with it. In the case of a two-pipe system, care must be taken in the determination of suitable pipe sizes in order to graduate them properly in diameter to obtain a proportionate distribution of the circulation through the various radiators by pipe sizing alone as far as possible. As there are, however, so few standard diameters of pipes, this is not always quite practicable, and so each radiator should be provided with two valves, one being a lock-shield pattern which can be permanently set for regulating the circulations. If this is not done there is a possibility of short-circuiting of the circulation through the radiators near the boiler; this, of course, would be to the detriment of radiators farther away.

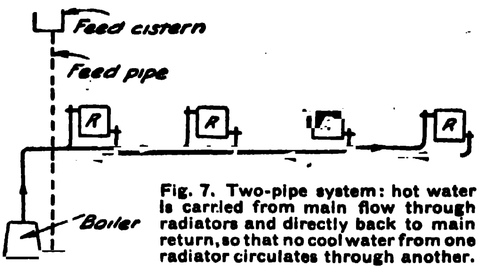


Fig. 7. Two-pipe system: hot water is carried from main flow through radiators and directly back to main return, so that no cool water from one radiator circulates through another.

Two-pipe Rising Mains System. When a domestic or other building of some height is designed with a basement and the rooms are of regular size placed one above the other on all floors as indicated in Fig. 8, a system like this is very suitable because all the large main pipes can be carried below the ground floor or overhead in the basement, with rising pipes of comparatively small diameter serving the

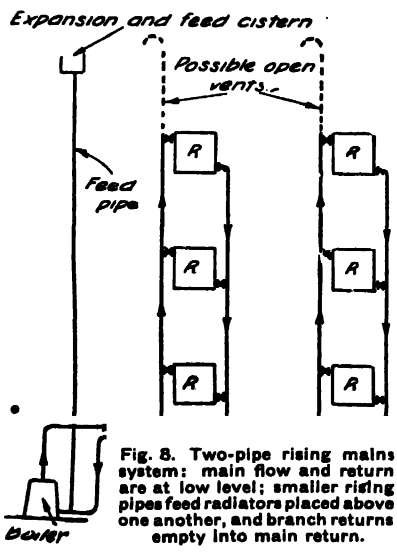
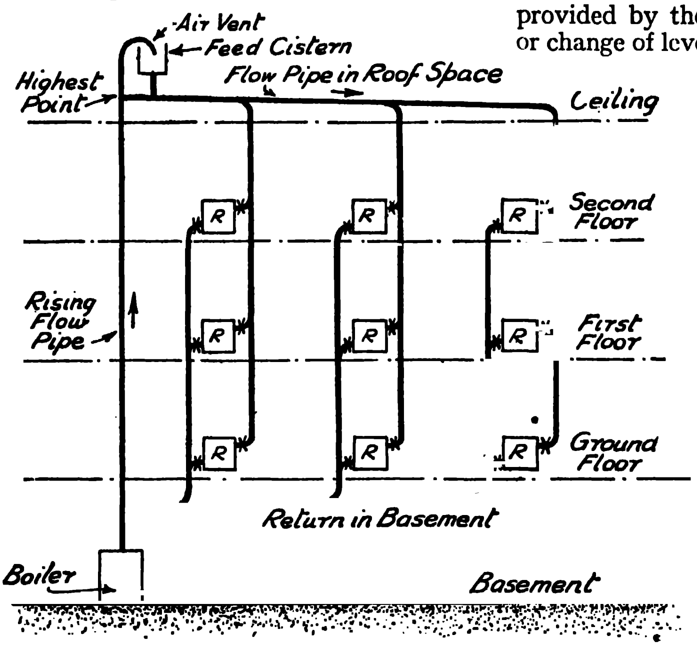


Fig. 8. Two-pipe rising mains system: main flow and return are at low level; smaller rising pipes feed radiators placed above one another, and branch returns empty into main return.

radiators on each floor of the building.

In a scheme of this design the radiators on the top floor would be liable to collect air and become air-locked unless the air taps are opened occasionally to let the air escape.

An alternative method would be to run an open-air pipe, which need be no more than $\frac{1}{8}$ or $\frac{1}{4}$ in. diameter, from each radiator on the top floor, to a height above the level of the water-level in the feed cistern.



HEATING: CENTRAL HEATING BY HOT WATER. Fig. 9. Two-pipe dropping system: rising main is vented at highest point; main flow slopes slightly downwards in roof space; drop feeds of diminishing diameters serve radiators placed one below another; drop returns of increasing diameters carry cooled water from radiators to main return in basement.

Two-pipe Dropping System. (Fig. 9.) An excellent scheme. In this the rising flow pipe from the boiler rises direct to the highest point, flows overhead on the top floor or in the roof space, with dropping flow pipes serving the radiators on the floors below. The flow pipes are graduated in size as each radiator is connected up, until the radiators on the bottom floor are served, and there the dropping flow pipes end.

Dropping return pipes start at the bottom outlets from the radiators on the top floor, and these pipes are increased in diameter as the returns from the radiators on the lower floors join into them, until after picking up the returns from the radiators on the bottom floor they are collected up into a main return carried under the floor or at the basement ceiling, back to the boiler.

Forced Circulation Systems. When a circulating pump is employed any of the typical designs may be used for the scheme, but there is a preference for the two-pipe system with flows and returns of mains and branches running parallel.

As a definite circulating pressure is provided by the pump, any rise and fall or change of levels at which the circulation pipes are run is of little consequence, the circulations can be dipped under or carried over doorways, as found desirable. Trouble from air lock in pipes is not so liable to occur as in a gravity system, because the force of the pump is generally able to carry the water forward and the air escapes at the first vent. It is, however, best to provide air taps at points where air might accumulate.

When a forced circulation is adopted the water may be circulated through the pipes and radiators at a higher mean temperature, as no drop of temperature is required for promoting circulation, as in a gravity system.

D. CALCULATION OF HEAT REQUIREMENTS FOR A BUILDING

The determination of heat requirements in the rooms of a building should be calculated in British Thermal Units per hour, but first of all definite inside and outside temperatures and the air change per hour must be decided upon.

For Britain the calculations are usually based upon obtaining a temperature of 60° F. in the rooms when the temperature outside is 30° F.; but in offices, dwelling houses and school classrooms for young children, 65° F. is often required inside the rooms when 30° F. outside. These temperatures should be obtained when the rooms are unoccupied.

In regard to air change, it is generally estimated that to allow three air changes per hour in a school classroom is sufficient

and a similar allowance can be made for rooms in offices and dwelling houses; but if mechanical ventilation is not contemplated and the decision of air change is left with the heating engineer, he will probably figure on one change of air per hour in each room. This is not unreasonable when it is considered that the calculations are made on the basis of the rooms being empty and that each person in occupation would emit about 300 B.Th.U. per hour; thus, occupation of a room, while calling for more ventilation provides extra heat to compensate for that ventilation.

For warming the air in a room the heat requirements per hour are easily calculated by multiplying the cubic contents of a room in feet by the number of air changes allowed; then by the coefficient 0·02, which will give the number of B.Th.U. required to raise the air 1° F. Then multiply by the number of deg. F. the air has to be raised from the outside temperature, and the result is obtained in B.Th.U. The correct coefficient for warming air is

0·019 B.Th.U. will raise 1 cu. ft. of air 1° F.,

but in calculations 0·02 is generally used.

Example. The air in a room 20 ft. × 20 ft. × 10 ft. high has to be raised from 30° F. to 60° F., allowing for three air changes per hour. How many B.Th.U. are required?

20 × 20 × 10 = 4,000 cu. ft.
4,000 × 3 × ·02 × 30 = 7,200 B.Th.U.

Warming the air alone is not sufficient, because enough extra heat has to be introduced to compensate for the loss of heat per hour through the building structure; these losses may easily be calculated from coefficients given in the article on Heat Loss (*which see*).

Requirements for a House. An example of the calculations necessary for the determination of heat requirements per hour in the rooms of a private house is given in the Chart facing p. 504.

The mean temperature of the water in a gravity hot water central heating system is usually about 160° F. when working at capacity, as it is customary to design a system to work with a flow temperature from the boiler of 180° F. and a return temperature to the boiler of 140° F.

For a pumped circulation the same mean temperature of water is frequently used, but the flow may be 170° F., with a drop of 20° F. to a return at 150° F.

If the air surrounding the pipes and radiators is 60° F. there will be a temperature difference between the mean water temperature and the air of 100° F., and it is generally within a very short range of these temperature differences that a hot water heating system is worked.

Table III on the Chart shows heat transmission from uncovered iron pipes in B.Th.U. per lineal foot per hour, 60° to 120° F. temperature difference.

The transmission from various types of radiators under similar conditions is shown by Table IV (printed on Chart) issued by Ideal Boilers and Radiators, Ltd.

The tables of heat emission will serve for the range of temperature differences in ordinary use, but as the heat emission does not rise or fall in direct proportion to the temperature difference—being proportional to the temperature difference to the 1·3 power—a convenient table is given of the values of $n^{1 \cdot 3}$ (*see* Table V, Chart facing this page). Here n represents the temperature difference between the mean temperature of the water and the air surrounding the pipe or radiator.

Effect of an Air Inlet Behind a Radiator. The effect of providing a fresh air inlet through an outside wall behind a radiator is to increase the heat emission by about 30 per cent. above that given in the table. Such increase does not mean that less heating surface will be required for warming a room, as extra incoming air has to be warmed. The extra heat emission has to be provided for, however, by more pounds of water circulated, by pipes of sufficient diameter to permit the extra pounds of water to circulate, and by boiler power to cope with the total maximum heat emission.

Radiators with Shelves Over, etc. The heat emission from a radiator is affected by the placing of a shelf above it, by it being placed in a wall recess, or by it being cased in with metal gratings, and the heat emission per sq. ft. per hour for 100° F. temperature difference is shown in Table VI (Chart facing this page).

Non-Conducting Covering on Hot Water Pipes. Although manufacturers of non-conducting composition, either of sectional type or plastic, sometimes claim up to 80 per cent. insulating efficiency, it is not usual in calculating the heat emission for determination of boiler power to allow a greater efficiency than 66⅔ per cent. It is therefore customary to calculate the

heat emission from pipes covered with non-conducting composition as being one-third the amount for exposed pipes.

Painting Radiators or Pipes. The effect on heat emission caused by painting any colour or with dull or enamel finish appears to be negligible; but for bronze powder, bronzing liquid and aluminium paints, about 12 to 15 per cent. should be deducted from the heat emission given in the Tables. If bronzing liquid having a cellulose base is used, the heat emission is reduced by about 17 per cent. *See further* under Radiation.

Surfaces Required for Radiators. An example of calculations is given on the Chart facing page 504, based on the plans in Figs. 10 and 11. The rooms are to be warmed by radiators alone; the factor is 160 B.Th. U. per sq. ft./hr. at 100° F. temp. difference.

Disposition of Radiators. The positions in which radiators are to be fixed should be governed mainly by obtaining the best distribution of heat. A number of small radiators give a better distribution than one large one, although the total heating surface may be exactly the same.

Radiators should be away from fireplaces which might be used for alternative heating, and are more effective if placed against outside walls or under windows. Other conditions which influence the selection of positions for radiators are the facility with which they can be served by pipe circulations and, to some extent, the disposition of furniture which may be placed in the rooms.

E. SELECTION AND DESIGN OF A CENTRAL HEATING SCHEME

The selection of a system of heating depends upon the type of building and the purpose for which it is to be used.

For public halls, cinemas and buildings where a large number of persons will assemble, air conditioning (*which see*) would be most suitable.

For schools, halls and churches, hot water in pipes and radiators is usually adopted (*see* Plate *f.p.* 497), and the circulation accelerated by a pump when the buildings are straggling or the levels unsuitable for gravity circulation.

In dealing with modern factory premises, hot water heating with pumped circulation is very satisfactory, the main pipe circulations being carried overhead with dropping connexions to radiators at or near floor level (*see* Plate *f.p.* 385). An alternative to use unit heaters (*which see*) instead of radiators. The unit heaters may be suspended overhead and the warm air delivered downwards. When a building is to be warmed by unit heaters placed at a high level a low pressure steam system with gravity return is very suitable.

Solid fuel slow-combustion stoves are sometimes used for engineering works where local heat is required and there is little danger from fire.

For private houses, hot water gravity systems with pipes and radiators are most popular, fireplaces and gas or electric points are generally provided in important rooms to permit alternative heating. Hot water for domestic services should never be drawn from a heating system with sectional type boiler, and not more than one or two ordinary radiators should ever be worked off a direct hot water supply system; even then, discoloured water may result. Towel rails of copper tubing or copper radiators do not discolour the water.

Referring to Figs. 10 and 11 (in Chart *f.p.* 504), suitable sizes for the radiators having been calculated and their positions shown on plans, the general run of pipe circulations can be studied.

It may reasonably be assumed that as little pipework as possible should be visible in the interior of the rooms, and the general plan of the building and positions of radiators suggest that a single-pipe dropping system would be suitable. The flow pipes could be carried in the roof space, the dropping pipes in corners and cased in, while the return pipes could be carried below the floors back to the boiler chamber.

Such a scheme is shown by Figs. 10 and 11 in Chart *f.p.* 504. As will be noted, a main flow riser is carried from the boiler direct to the roof space, where it is vented above the feed cistern at the highest point. The main flow runs in the roof space, sloping gently downwards and branching to one drop in corner of Bedroom 3, serving one radiator 35 sq. ft. in Bedroom 2 and one radiator 33 sq. ft. in Bedroom 3. This drop then continues through the Kitchen and serves one radiator 20 sq. ft. in Dining-room. Another drop is taken in corner of Bedroom 2 and corner of Dining-room, serving a radiator 20 sq. ft. in Dining-room. These two dropping pipes join

into a return pipe under the floor back to the boiler.

A dropping pipe is carried in corner of the Landing, serving one radiator 36½ sq. ft. in Bedroom 4 and one radiator 30 sq. ft. on Landing. The drop then continues in corner of Hall, serving one radiator 38½ sq. ft. in Lounge and one radiator 30 sq. ft. in Hall; then returns below floor. Another pipe drops in corner of Bedroom 1, serving a radiator 50 sq. ft. in that room, and then continues dropping in corner of Lounge, serving one radiator 38½ sq. ft., and afterwards is carried below the floor, joining into the return from the drop in Hall, and then continues back to the boiler. The small radiator in Scullery is served from this return pipe.

The central heating scheme for the house in Figs. 10 and 11 (in Chart *f. p.* 504) has now been designed, and suitable diameters for the pipe circulations can be determined.

No reduction will be permissible in the size of the radiators because of the heat emission from pipes helping to warm the rooms, as the flows are in the roof space, the dropping pipes will be cased in, and the return pipes under floor covered with non-conducting composition.

Calculation of Approximate Pipe Sizes. First ascertain the pounds of water to be circulated through each pipe, based upon 40° F. temperature drop. The radiators were taken as emitting 160 B.Th.U. per sq. ft. per hour, and with a 40° F. temperature drop the water which would require to be circulated per hour for each sq. ft. of radiator would be:

$$\frac{160}{40} = 4 \text{ lb.}$$

This would not be sufficient, because enough extra water has to be circulated to make up for the heat emission from the pipes; but as these have not yet been sized an approximation must be made and about 50 per cent. added on for transmission from pipes, which brings the amount of water per sq. ft. of radiator surface to 6 lb.

The amount of water per hour through each pipe can now be marked on the plans:

Loop circulation	A	88½ sq. ft.	× 6		531 lb.
„ „	B	135 „	× 6		810 lb.
„ „	C	20 „	× 6		120 lb.
„ „	D	88 „	× 6		528 lb.
Radiator in scullery		18 „	× 6	=	108 lb.

See further under Pipe Sizing.

Total Circulating Pressure. The loop circulation A which serves the radiator in Bedroom 1 and far radiator in Lounge is undoubtedly the "index loop," as the travel is the farthest from the boiler. The average circulation height of this loop is obtained thus:

1 radiator	50 sq. ft.	× 10 ft. above boiler	=	500
1 „	38½ „	× 0 „ „	=	0
	88½			500

$$\frac{500}{88 \cdot 5} = 5 \cdot 6 \text{ ft. average circulation height.}$$

Based upon a 40° F. drop in water temperature, the circulating pressure due to the radiator height is:

$$5 \cdot 6 \times \cdot 163 = \cdot 9128 \text{ in.}$$

To this may be added the circulating pressure obtained by a 10° F. temperature drop in the pipe in roof space at a circulation height of 10 ft.

$$10 \text{ ft.} \times \cdot 044 = \cdot 4400 \text{ in.}$$
$$\text{Total } 1 \cdot 3528 \text{ in.}$$

Travel of Index Circulation. The travel of the "index circulation" from the boiler around loop A and back to the boiler is 180 ft., and adding 25 per cent. for resistance of valves and fittings the total travel is 225 ft.

The average circulating pressure per 10 ft. of travel will be:

$$\frac{1 \cdot 3528 \times 10}{225} = \cdot 06 \text{ in. per 10 ft.}$$

Suitable diameters of all the pipes may now be taken from the friction table (Table VII in Chart *f.p.* 505).

The circulation pipes have now been approximately sized, but to make quite sure that the pounds of water to be circulated were correctly approximated a check can be made by working out the total heat emission from pipes and radiators. This will also be required to arrive at the necessary boiler capacity.

Connexions to Radiators. Where connexions to the radiators are taken from a single-pipe circulation, they may, if near the main pipe, be sized as follows:

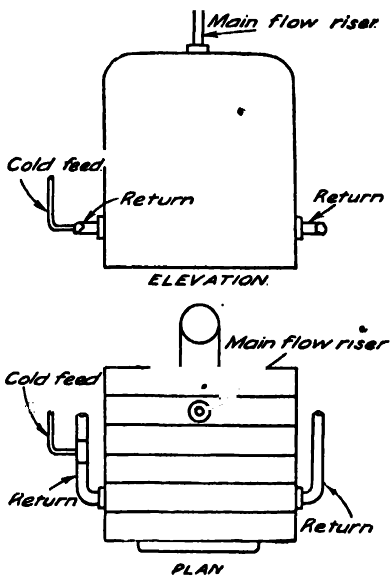
	Sq. ft.		Sq. ft.	
To radiators up to	18	.. .. ..		½-in. dia.
„ „ over	18	and up to	40	¾ „ „
„ „ „	40	„ „ „	72	1 „ „
„ „ „	72	„ „ „	112	1¼ „ „
„ „ „	112	„ „ „	160	1½ „ „

If the radiators are a little distance from the main pipe the diameter should be a size larger.

Capacity of Boiler. Manufacturers of sectional boilers for central heating always advocate that an extra section, or about 20 per cent. margin of capacity should be allowed when selecting a boiler. This does not mean that the boilers are over-rated, but it allows a margin for first warming up from the cold state.

When an apparatus is started up, the air around the pipes and radiators may be very cold; owing to a big temperature difference the heat emission will be very large, and the boiler has to cope with this. When the air around pipes and radiators has been raised to about 60° F. (normal working conditions), the heat emission is reduced and the margin of power possessed by the boiler enables it to be stoked very moderately for maintaining the required result. For the example given in the Chart (Figs. 10 and 11), dealing with an installation for a private house, the heat emission from pipes and radiators has finally been calculated as 79,810 B.Th.U. Adding 25 per cent. to this, the suitable capacity of the boiler will be 95,772 B.Th.U. per hour, and one may be selected which is listed near this capacity.

Pipe Connexions to Boiler. If the distribution of heat is to be effected by one or two circulations from a sectional boiler, it is best to take the main rising flow pipe from the top of a section near the back section, at a point where the most fierce heat from the furnace will impinge (*see* Fig. 11). The main flow should preferably be taken to the highest point of the circuit and then divide up into branch circulations if required. The returns of circulations should connect to the boiler near the front section and at each side.



HEATING: CENTRAL HEATING BY HOT WATER. Fig. 12. Flow and return connexions to a sectional boiler, the latter being shown in elevation and plan: main flow riser is taken from section near back, and returns connect to one near front.

F. CHOICE OF FUEL AND ITS USE

Heat is the lowest form of energy, as mechanical or physical work degenerates into heat. The combustion of fuel, when by ignition oxygen combines with carbon, produces a chemical action which generates intense heat. Fuels, such as wood, coal, coke or oil, are accordingly used for firing boilers for heating or hot water supply.

The selection of any particular type of fuel depends very much upon its price compared with other fuels and the ease with which it may be obtained. Each type of fuel which can be used has a certain calorific value which represents the B.Th.U. available from each lb. of the substance.

For instance:

	B.Th.U. per lb.		
Wood has a calorific value of	4,200	to	5,600
Coal ,, ,, ,,	12,000	,,	14,000
Coke ,, ,, ,,	10,200	,,	13,200
Oil ,, ,, ,,	18,000	,,	19,000

These calorific values of fuel are ascertained by tests in which a small sample of the fuel immersed in water is subjected to perfect combustion by electric ignition. The temperature of the water discloses the calorific value of the fuel as:

1 lb. water is raised 1° F. by 1 B.Th.U.

The selection of a medium for heating does not entirely depend upon the price of fuel and its calorific value, because whatever method is adopted for generating and transmitting heat there is sure to be some waste, such as heat passing to a boiler flue, and so 100 per cent. efficiency from fuel is seldom—if ever—obtained.

Manufacturers of boilers and all apparatus for generating and transmitting heat have a definite object, which is to obtain the highest efficiency from the fuel used, and to design the apparatus to be worked with a fuel which will be cheap and still have a high calorific value.

If heat is required for warming a building or the supply of hot water—then to obtain that heat a certain amount of solid, liquid or gaseous fuel or electric current *has* to be used, and the apparatus which will enable this heat to be distributed in the most agreeable, easy and economical

manner is the one to select (*see further under* Fuel).

Relation Between Heating and Ventilation. To restrict ventilation in order to economise warmth is a very common mistake and often causes some methods of warming to be brought into disrepute.

The open fireplace is an excellent ventilator but a waster of heat. A room heated, but not ventilated, becomes stuffy, and the occupants experience discomfort; this is not surprising, as heat is given off to the extent of about 300 B.Th.U. per hour from each person. Heating and ventilating must be arranged conjunctively in order to give conditions of comfort.

Need For Air Conditioning. Under certain conditions of climate or circumstances it might be impossible to keep the interior of a room or building comfortable for occupation by warming and ventilation alone; some cooling medium and air humidifying or de-humidifying is necessary. This process embracing filtration and washing of the air, cooling or heating, humidifying or de-humidifying, is termed Air Conditioning. It is described under that heading in Vol. I.

G. TEMPERATURE GUARANTEE & TESTING

It could not be expected that anyone purchasing a central heating apparatus would do so without receiving some guarantee that the desired result would be obtained; and the heating engineer should bear in mind that a little extra heat given will be more satisfactory than a shortage of heat.

Although the data and coefficients given have been in practical use for a long time, there have been no demonstrations that they are incorrect. Failures to obtain satisfactory temperature results can be usually traced to one or a combination of some of the following reasons:

(*a*) Under-estimation of the heating surface required.

(*b*) A greater air change in the rooms than has been allowed for.

(*c*) Insufficient boiler power, or inferior fuel or stoking.

(*d*) Bad draught of a chimney.

(*e*) Incorrect pipe sizing.

(*f*) Bad design of a scheme causing air pockets, or lack of circulation pressure.

When giving a guarantee the statement should be avoided that an apparatus will give a certain number of deg. F. inside the building above the outside temperature, because the temperature obtained in a building by a heating apparatus does not rise in direct proportion to the outside temperature. The guarantee should clearly state that a definite inside temperature will be obtained when a definite temperature prevails outside—say, 60° F. inside when 30° F. outside.

Since a test cannot always be arranged for a time when there is a specified temperature outside, a comparative scale of inside and outside temperatures can be used—see Vol. III, page 928. It deals with outside temperatures from 20° F. to 65° F. and consequent inside temperature results, based on a specified internal temperature of 60° F. when 30° F. outside. Thus:

Internal	57° F.	60° F.	62° F.	65° F.	67° F.
External	25° F.	30° F.	35° F.	40° F.	45° F.

The guarantee should state the number of air changes per hour which have been allowed for in the rooms of a building, because excessive leakage or mechanical ventilation may easily cause failure to obtain a satisfactory inside temperature if no allowance has been made for such conditions.

The temperature of 30° F. outside as a standard for testing is better than 32° F. which is so frequently used, because at 32° F. drastic changes in outside conditions may be taking place, such as ice and snow turning to water, when every lb. of ice turning to water takes up 142 B.Th.U. latent heat. This has a marked effect upon temperatures and conditions of comfort.

H. GENERAL CONSIDERATIONS OF COST

The cost of heating a building should be considered on two points, viz.:

Initial cost of installation.

Cost of maintenance and running expense in fuel consumption and labour.

The cost of a heating apparatus does not vary much for different schemes of hot water, steam or unit heater systems. These are moderate in cost of installation, they can be worked with a cheap type of fuel and call for very little attention and labour.

Installations worked by gas or electric radiators may be installed probably at less cost, but although the labour cost is less, the price of gas or electric current will probably increase working expense

to a figure above the fuel and labour costs of an ordinary coke-fired apparatus.

Speculative Building. When houses are being built for sale the gas and electric companies often provide points at an exceedingly moderate cost, and if a gas or electric water heater is provided it then rests with the tenant or purchaser to face the cost of gas or electric current.

It is very seldom that a dwelling-house built for sale has a complete central heating system installed; it is more likely that a small independent hot water supply boiler will be directly connected to a storage cylinder, and possibly a towel rail may be provided in the bathroom, and a radiator in the entrance hall. These cost very little, and are very attractive to a prospective purchaser.

J. STRUCTURAL REQUIREMENTS

For large buildings the boiler house should be commodious, with doors or passages wide enough to admit the various parts of the heating plant. There should be direct communication with the outer air, as fresh air supply is very essential for the perfect combustion of fuel. The chimney should be lined with firebrick, and have an air space between the firebrick and the main brickwork. It should be of the correct height and inside area. There should be a cleaning door at the foot of the chimney, and the boiler flue connexions should be built-in perfectly airtight and not allowed to project inside the flue and restrict the area. For suitable dimensions of chimneys, *see* Chimney: (1) pp. 228-231.

Care should be taken that accommodation is made for high-level cold water storage tanks of suitable capacity. The building should be constructed to give proper support for these, and the tanks should preferably be situated near the main chimney shaft or in a position where they cannot be affected by frost.

The builder should provide the cold water storage cisterns and lay on the cold water from the main supply to them, but the heating engineer usually provides the combined feed and expansion cistern, and the connecting pipe to his apparatus.

Positions and sizes of any trenches, chases and holes through walls or floors should be given to the builder, in order that early preparations can be made, as it is very difficult and costly to cut holes through ferro-concrete when it is once set, but quite simple to make good after the pipes have been placed in position.

When town gas is to be used as a fuel, arrangements should be made with the gas company to supply the meter and run necessary piping to boiler or heater.

In many districts gas is available for heating purposes at a much reduced cost.

When electric power is required for either heating, driving fans or circulating pumps, the electric supply company should provide the mains and the necessary meters and main switches. Electric current for power is generally supplied at a cheap rate, and if used for heating water on the thermal storage system the current taken at certain periods may be considerably cheaper.

HEATING: (3) CENTRAL HEATING BY STEAM

By Louis J. Overton, M.I.H.V.E.

Stating the heat requirements of a building to be warmed, and giving tabular and other information about properties of steam, emission from pipes and radiators, etc. It includes the design of a Steam Heating Scheme. See Boiler; *also* Steam. For a method of warming a factory under steam pressure *see* Factories: (3) Heating, page 390A.

When a steam heating system is to be installed in a building the heat requirements in British Thermal Units per hour should be calculated in exactly the same manner as for a hot water system.

There is not the same heat lag with steam heating as there is with hot water. The water takes longer to absorb and distribute the heat, while steam gets up full heating temperature very quickly and then as quickly cools down. The speed with which steam heat can be raised and distributed and the speed of cooling down are an advantage, but the heat lag of a hot water system (which does not fluctuate so quickly and takes longer to cool) is also an advantage.

Pressure of Steam. Steam at 0 lb. gauge pressure contains 1150·7 B.Th.U. in 1 lb., and of this 970·7 B.Th.U. are latent heat. Steam at 200 lb. gauge pressure contains 1204·8 B.Th.U. in 1 lb., and of this

842·7 B.Th.U. are latent heat. This and other readings may be taken from Table I.

TABLE I.

Properties of Steam

Gauge pressure	Temp. in deg. Fahr.	Latent heat B.Th.U. per lb.	Total heat above 32° F. per lb.
0	212·0	970·7	1150·7
0·3	213·0	970·2	1151·2
1·3	216·3	968·1	1152·5
2·3	219·5	966·2	1153·7
3·3	222·4	964·4	1154·9
4·3	225·2	962·6	1156·0
5·3	228·0	961·0	1157·1
6·3	230·6	959·4	1158·1
7·3	233·1	957·8	1159·1
8·3	235·5	956·3	1160·0
9·3	237·8	954·8	1160·9
10·3	240·1	953·3	1161·7
11·3	242·2	952·0	1162·5
12·3	244·4	950·7	1163·4
13·3	246·4	949·3	1164·1
14·3	248·4	948·1	1164·9
15·3	250·3	946·7	1165·5
20·3	259·3	941·0	1168·8
25·3	267·3	935·6	1171·6
30·3	274·5	930·8	1174·1
40·3	287·1	922·0	1178·3
50·3	298·0	914·4	1181·8
60·3	307·6	907·5	1184·7
70·3	316·3	901·1	1187·3
80·3	324·1	894·1	1189·7
99·3	337·4	883·9	1193·3
149·3	365·6	862·0	1200·1
200·3	388·0	842·7	1204·8

For an extended table *see under* heading Steam.

As the greater part of heat given off by steam is due to condensation releasing the latent heat, there does not appear to be much advantage in using steam at a high pressure for heating purposes. Even exhaust steam emerging at zero pressure from an engine exhaust gives up 970 B.Th.U. per lb. when condensing to water.

In countries where buildings are carried to a very great height, the head pressure on a hot water heating boiler would be considerably more than the steam pressure which would be required to distribute steam through pipes and radiators. For example, if a building is 500 ft. high the head of water would be about 215 lb. per sq. in., while a steam boiler could warm the building with steam at an initial pressure of about 10 lb. per sq. in., and there would be no heavy weight of water in radiators and pipes on the many floors of the building.

Emission of Heat from Steam. The initial boiler pressure and temperature cannot be expected to extend far into the pipes and radiators of the heating system, for in the act of emitting heat the pressure and temperature will drop as condensation takes place. Therefore it is usual to base calculations for pipes and radiators on a temperature difference of 155° F. or 160° F. between the steam in the pipes or radiators and the air surrounding them.

Table II gives heat emissions from steam pipes, based upon steam at 215° F. to air at 60° F., and steam at 220° F. to air at 60° F. Any emissions due to variations of temperature difference can be calculated from Table III in Heating Chart *facing page* 504.

TABLE II.

Transmissions from Steam in Iron Pipes in B.Th.U. per lineal foot per hour.

Nominal dia. of pipe	155° F. Difference	160° F. Difference
½ in.	99	103
¾ ,,	123	129
1 ,,	141	147
1¼ ,,	173	180
1½ ,,	194	202
2 ,,	228	238
2½ ,,	272	283
3 ,,	331	345
4 ,,	409	426
5 ,,	500	522
6 ,,	585	610

For radiators the manufacturers issue data about heat emission from their various patterns; the following Table III refers to "Ideal" Radiators manufactured by Ideal Boilers & Radiators, Ltd.

TABLE III.

Transmissions from Steam in Radiators in B.Th.U. per sq. ft. per hour.

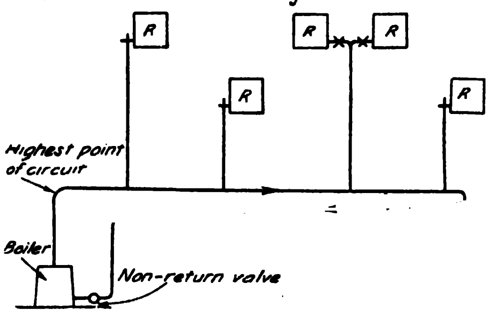
"Ideal" Radiators	155° F difference	160° F difference
Neo-Classic 2 Column ..	327	340
do. 4 ,, ...	300	312
do. 6 ,, ...	282	294
do. Window ..	278	290
Hospital 3 in. ..	327	340
do. 5¾ ,, ..	278	290
do. 7¼ ,, ..	264	275
Classic Wall	300	312
Plain Wall (bars vertical)	282	294
Plain Wall (bars horizontal) ..	181	189
Plain Single Column ..	282	294
,, Two ,, ..	275	287

A. STEAM CENTRAL HEATING METHODS

The use of steam for heating buildings has been practised for many years. At one time the motive power for driving machines in workshops and factories, and the supply for laundry and cooking in large institutions, was always produced by

steam generated at about 50 to 100 lb. pressure in large steam boilers—generally of the Cornish or Lancashire type, set in brickwork.

If heat was required in any workshop, office or room it merely meant that a



HEATING: CENTRAL HEATING BY STEAM. Fig. 1. Single-pipe steam heating system with gravity return: single risers connect radiators with steam main, which slopes downwards from highest point at top of main riser.

branch was taken from the main steam pipe to a line or a coil of piping in the room to be dealt with, and a small valve at the lowest point of the coil would be left slightly open to allow the water of condensation to trickle out. This water of condensation, at about 212° F., was sometimes collected in a tank, and where conveniently possible would be used as boiler feed water. If this was not practicable the hot water was used for other purposes or run to waste.

Such heating systems worked quite well, for the pressure of the steam forced air and water before it until the air and water were both expelled through the slightly open end and the coil was filled with steam.

Today in many buildings where machinery is installed no steam is required, as the motive power is provided by electric motors. Under these conditions, where a steam boiler is needed for a heating apparatus alone, there would be no particular object in providing steam at a high-pressure. Therefore a sectional type of steam boiler is quite suitable.

Steam pipes carried overhead in workshops or baths are very serviceable in the counteraction of down draughts and of atmospheric condensation on ceilings, but heating by steam pipes carried solely overhead is often very unsatisfactory.

Schemes with Pipes and Radiators. When radiators and pipe connexions from a steam boiler are used for central heating in a building, the design of a scheme may be very similar to a hot water heating system, and generally steam systems may be classed under the following headings:

Single-pipe Gravity Return System. The general principle of this system is illustrated by Fig. 1. From the boiler a single-pipe circuit is taken, the return being taken into the bottom of the boiler; a non-return valve is fitted near the boiler to prevent pressure forcing water out of the boiler along the return pipe. From the single circuit pipe, rising single pipe connexions are taken to the bottoms of radiators; automatic air valves at the top of the radiators allow air, but not steam, to escape. Similar schemes are used in America, but not much in Britain, where the two-pipe system is generally installed.

Two-Pipe Gravity Return System. In the design of a steam system of heating it is advisable to provide for draining the water of condensation from a steam pipe or radiator as soon as possible, and to slope the pipes so that steam and water of condensation both travel together in the same direction until the water can be drained through a steam trap or run back into the boiler by gravity.

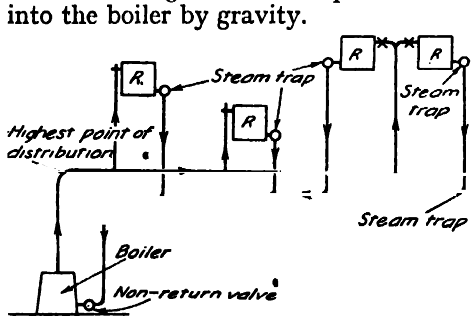


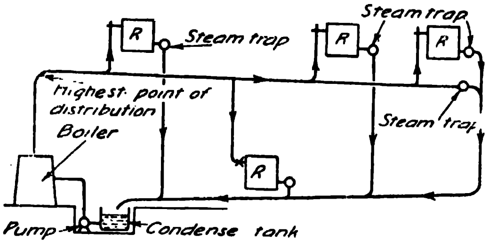
Fig. 2. Two-pipe steam heating system with gravity return: risers, from downward sloping main enter radiators at top; branch returns carry water of condensation from steam traps to main return, and thence to boiler (see *also* Fig. 6).

Fig. 2 shows a two-pipe gravity return system. The main steam pipe rises from the boiler, and the horizontal distributing pipe slopes downwards with branches to radiators; at the end of the steam main a trap allows water of condensation from the main to enter a return pipe. The steam connexions to radiators enter at the top, and a steam trap at the bottom of each radiator allows water of condensation to empty into a main return pipe to the boiler, where it enters the boiler through a non-return valve.

Except in a few instances where steam pipes rise vertically, the steam and water formed by condensation travel in the same

direction, and there should be no noise caused by conflict between steam, air and water, which so often occurs in badly designed steam systems.

Two-pipe Open Return System. It is evident that if the boiler is worked at a pressure higher than the water head



HEATING: CENTRAL HEATING BY STEAM. Fig. 3. Two-pipe steam heating system with open return and pumped boiler feed, used when water of condensation cannot return by gravity.

pressure of the condense return, the water of condensation cannot return by gravity to the boiler, and in such case an open return system is used. Fig. 3 shows a two-pipe system with open return. The main steam pipe is taken from the top of the boiler and distributes to the radiators. The water of condensation released through steam traps from the radiators is collected into a main return pipe, similar to a gravity return; but in this case the main condense pipe delivers into a condense water cistern, whence the hot water is pumped back into the boiler.

Vapour and Vacuum Systems. There are several methods having distinctive titles and protected by certain patent rights, which are used in connexion with steam heating. They mainly deal with the use of exhaust steam or steam at a very low pressure, and with the collection by means of a vacuum pump of the water of condensation for return to the boiler.

Steam Heated Calorifiers. Steam can be used in calorifiers either for heating water for hot water heating circulations, or for heating water for baths and domestic services. All the water of condensation from calorifiers is pure, and suitable for pumping back into the boiler.

Exhaust Steam Used for Heating. When exhaust steam issues from an engine it is without pressure, but still has most of its original heat value. Sometimes it is delivered in pipes to the radiators of a heating system, and by means of a vacuum pump acting on the condense outlets from the radiators an excellent distribution of heat is obtained.

Exhaust steam is often used for heating water in calorifiers, and when this is done the steam should first be passed through a grease eliminator, as where the water of condensation is returned to the boiler it should not contain any suspended grease.

The average amount of heat in exhaust steam from an engine is about 27,720 B.Th.U. per hour per horse power.

B. LOW PRESSURE STEAM SECTIONAL BOILER AND CONNEXIONS

Many types of sectional boiler may be used for either steam or hot-water heating systems, the only difference being that on a boiler used for steam a glass gauge has to be fitted which shows the water level inside the boiler, and instead of a thermometer a dial steam pressure gauge has to be provided.

The rating of a steam boiler in B. Th.U. per hour is exactly the same as for a hot water boiler of the same pattern, size and boiler heating surface.

Although theoretically only a small diameter main steam riser from the top of the boiler may be required, it should actually be kept for a short distance the same diameter as the outlet flange on the boiler, which is always fairly large. The reason for this is to prevent steam passing from the boiler at too high a velocity and carrying with it water from the boiler.

Above the sectional steam boiler a header pipe of full boiler outlet diameter should be formed, and from this the main steam rise taken of correct diameter for supplying the steam to the heating system. From the bottom of the header pipe above the boiler a pipe should be taken down and connected to the boiler at a low level (*see* Fig. 4). This pipe connexion is to

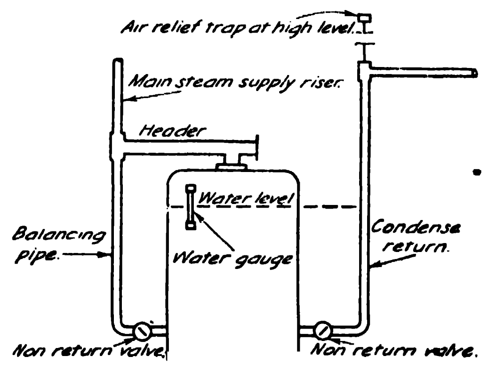
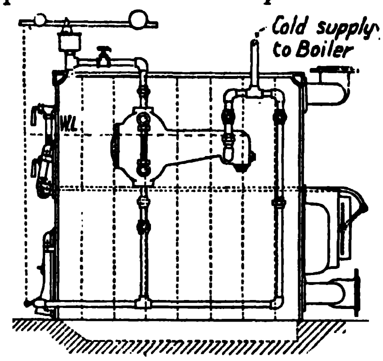


Fig. 4. Pipe connexions to low pressure steam sectional boiler: main supply rises from header above boiler, and balancing pipe is carried down to bottom of boiler to equalize pressure; return enters boiler opposite balancing pipe.

equalize the pressure, and is called a balancing pipe.

On the condense return pipe, well above water level, a rising vent pipe should be taken and provided at the top with an automatic air vent, which will allow air to pass but not steam.

Boiler Feed. A steam boiler, while in operation, may be replenished with water from any supply which has a head pressure greater than the working pressure in the boiler. Many boilers have been fed with cold water merely by a connexion direct from the district main water supply, when the turn of a valve by hand admits water to the boiler, but this method is not usually allowed by municipal authorities.



HEATING: CENTRAL HEATING BY STEAM. Fig. 5. "Ideal" immersed-valve automatic boiler feeder for supplying cold water to boiler: useful where steam pressure is less than 20 lb. and water pressure is less than 35 lb. and is constant. W.L.=water line.
Ideal Boilers and Radiators, Ltd.

When feed water is supplied from a tank at sufficient height above the boiler water line, it may be admitted by opening a valve; but water may be admitted automatically to the boiler as required by installing an "Ideal" immersed-valve automatic boiler feeder, as illustrated by Fig. 5.

This appliance is placed alongside the boiler at the level of the water, and as the water drops, a ball valve in the feeder opens, admitting water to the boiler; it closes again when the water reaches the correct level. A by-pass connexion is provided, to enable the boiler feed to be operated also by hand.

When the steam pipes and radiators used for heating are at the same level or below the water level of the boiler, the water of condensation should be collected into a tank from which the condense water and any new water required is delivered into the boiler by a boiler feed pump.

C. DESIGN OF STEAM HEATING SCHEME

In the design of a steam heating system it is desirable to carry the main steam pipe to the highest point of distribution, and from that point the water of condensation, as it is formed, should run downwards by gravity, as it is collected from the radiators. Fig. 6 shows four radiators, each having 40 ft. of heating surface, connected up by steam and condense pipes to a sectional steam boiler, for a gravity return steam heating system. The general idea on which such a system is designed is to carry a vertical steam pipe from the steam header over the boiler to the highest distributing point (marked A), and from there the steam pipe slopes downwards with rising connexions to the top of each radiator.

At the bottom outlet of each radiator is a steam trap, and another steam trap is placed at the extreme end of the main steam pipe, draining the condense water into the return pipe; the latter also collects the water of condensation from all the radiators. The main return slopes downwards towards the boiler, drops, and enters the boiler well below the water level. A non-return valve is fixed on the main return just before it connects to the boiler.

Calculating Pipe Diameters. The general arrangement of steam and condense pipes—shown by Fig. 6—may be

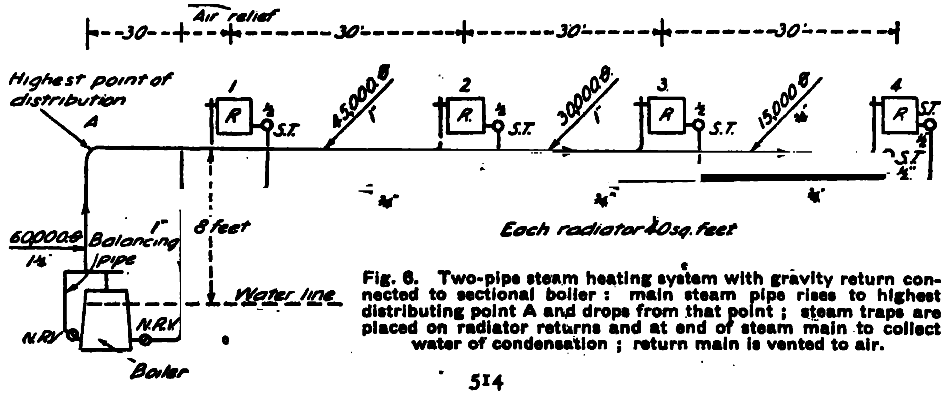
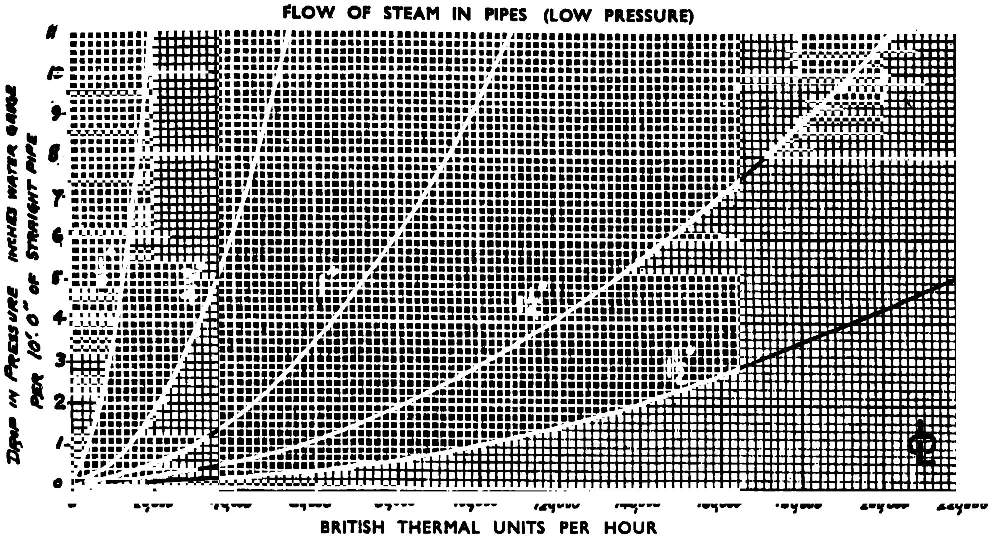


Fig. 6. Two-pipe steam heating system with gravity return connected to sectional boiler: main steam pipe rises to highest distributing point A and drops from that point; steam traps are placed on radiator returns and at end of steam main to collect water of condensation; return main is vented to air.



HEATING : CENTRAL HEATING BY STEAM. Fig. 7. Calculating pipe diameters for steam heating system : curved lines represent required diameters for given B.Th.U. when average pressure drop per 10 ft. is known (see text for calculations). Diagram is continued in Fig. 8, below.

used for illustrating a method of calculating suitable pipe diameters, in the following manner:

The steam trap, at the lowest level above the boiler, is about 8 ft. higher than the water level in the boiler. This gives a maximum head pressure of 8 ft. in water of condensation, equivalent to:

$$8 \text{ ft.} \times 0{\cdot}43 = 3{\cdot}44 \text{ lb. per sq. in.}$$

If the steam boiler is worked at 2 lb. pressure per sq. in., a gravity return would be possible; and if ½ lb. pressure of steam is allowed for at the valve of the farthest radiator (No. 4), the pressure drop between the outlet from the boiler and the valve of radiator No. 4 would be 1½ lb. It is found more convenient to express this in total pressure drop and the average pressure drop per 10 ft. of travel in equivalent inches water gauge. In this case the total water gauge is:

$$\frac{1{\cdot}5 \times 12 \text{ in.}}{{\cdot}43} = 42 \text{ in. total water gauge.}$$

The travel of steam from the boiler to radiator No. 4, including 25 per cent for resistance of fittings, etc., is 160 ft., and the average pressure drop per 10 ft. of travel is:

$$\frac{42 \text{ in.} \times 10}{160} = 2{\cdot}6 \text{ in.}$$

The amount of heat required (in British Thermal Units per hour) which has to be

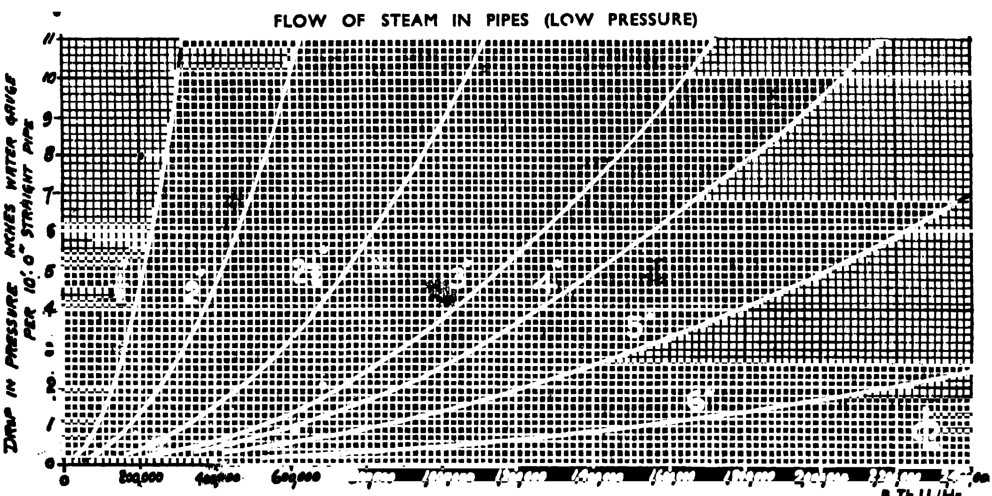


Fig. 8. Pipe diameters : continuation on smaller scale of Chart given in Fig. 7.

supplied through each steam pipe should be marked on the diagram. The heat required can be based upon the heat emission from radiators plus an approximate percentage for heat emission from the steam pipes.

Assuming radiators having a heat emission of 300 B.Th.U. per sq. ft. per hour have been selected, then each 40 sq. ft. radiator will emit:

40 × 300	= 12,000	B.Th.U.
Add to this 25 per cent. for emission from pipes	= 3,000	per hour ,,
Heat required per radiator	= 15,000	,,

Referring to Fig. 6, p. 514 it will be noted that:

The steam pipe serving radiators:

Nos. 3 and 4 ..	.. carries 30,000	B.Th.U.
Nos. 2, 3 and 4 ..	,, 45,000	,,
Nos. 1, 2, 3 and 4 ..	,, 60,000	,,

Knowing the B.Th.U. to be supplied by each length of steam pipe and the average pressure drop of 2·6 in. per 10 ft., we are now enabled to read the suitable diameter for the steam pipe from the charts (Figs. 7 and 8). Reading from the B.Th.U. per hour at the bottom of the chart, follow the vertical line until it cuts a horizontal line from 2·6 in. on the left hand of the chart; then the heavy curved line below this point may be taken for the suitable pipe diameter.

Dealing with the example illustrated by Fig. 6, the suitable pipe diameters will be as follows:

The steam pipe serving radiators:

No. 4	15,000 B.Th.U.	..	¾ in.
Nos. 3 and 4 ..	30,000 ,,	..	1 ,,
Nos. 2, 3 and 4 ..	45,000 ,,	..	1 ,,
Nos. 1, 2, 3 and 4	60,000 ,,	..	1¼ ,,

The pipes having been sized, a check can be made to ascertain exact duties.

				B.Th.U.
Radiators	160 sq. ft.	× 300	=	48,000
1¼-in. piping	38 ft.	× 173	=	6,574
1-in. ,,	60 ft.	× 141	=	8,460
¾-in. ,,	30 ft.	× 123	=	3,690
		Total ..		66,724

This is in excess of the 60,000 B.Th.U. first calculated upon, but on correcting the B.Th.U. emission against each pipe on the basis of 66,724 B.Th.U. total and 16,681 B.Th.U. for each radiator, the pipe sizes taken are still quite large enough.

For steam pipes below the floor and covered with non-conducting composition, use one-third of heat emissions given above.

Condense Pipes. The return pipes may be much smaller in diameter than the steam pipes; but in order to allow the water to run freely back to the boiler, they have been sized on the diagram (Fig. 6, p. 514) for a half-inch trap from each of the radiators and from the end of main steam pipe, with return pipes one standard size diameter less than the corresponding steam supply pipes. Sizes of pipes for water of condensation may be approximated from following Table:

	B.Th.U.		B.Th.U.	
		Up to	15,800	½-in. dia. pipe
From	15,800	,,	59,500	¾ ,, ,, ,,
	59,500	,,	158,000	1 ,, ,, ,,
	158,000	,,	316,000	1¼ ,, ,, ,,
	316,000	,,	470,000	1½ ,, ,, ,,
	470,000	,,	870,000	2 ,, ,, ,,
	870,000	,,	1,600,000	2½ ,, ,, ,,
	1,600,000	,,	1,850,000	2¾ ,, ,, ,,
	1,850,000	,,	2,370,000	3 ,, ,, ,,

HEATING: (4) BY ELECTRICITY

By L. C. C. Rayner, A.I.E.C.

Local warming by means of electric fires, radiators, convectors, panels or tubular heaters. For immersion heaters see that heading. See *also* Heat Loss; Panel Heater; Radiant Heating

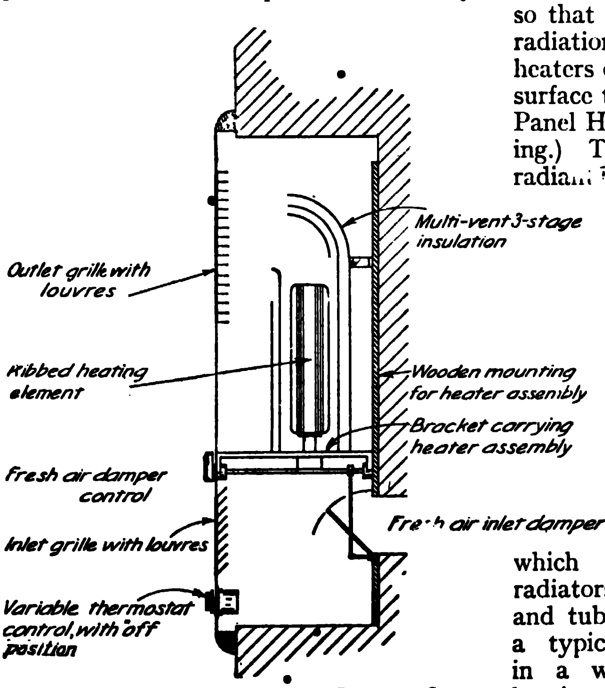
Heating by electricity may be divided under two headings: direct application and indirect application. The first consists in conversion of electricity into heat in the room actually being warmed. This will be effected by electric fires, radiators, convectors, panels or tubular elements, and may be called local heating. The second application is to central heating, when the distribution of heat to the rooms is effected by hot water or steam pipes and radiators. In this case the generation of the steam or warming of the water will be by electricity at one central point.

Calculation of Heat Losses. The design of an electrical heating installation is comparatively straightforward. When local heating is employed the first step should be the calculation of the heat losses from the various rooms. This should be carried out in exactly the same way as for the application of hot water heating. Information on this subject will be found under the heading Heating: (2) and Heat

Loss. If the heating is solely by electricity the heat loss calculations should be made for the normal room temperatures assuming an outside temperature of 30° F. When electricity is to be applied as an auxiliary to hot water heating or to heating by fires, it will usually be sufficient to base the calculations on a 10° to 15° F. difference between inside and outside temperatures.

Since electricity is easily and instantly controlled it is often used for warming rooms which are seldom used. In such cases, if the rooms when they are in use are occupied by sedentary workers it is necessary to add a considerable margin to the normal heat loss calculations. It will probably be desired to warm the rooms quickly; and, moreover, a higher than usual air temperature should be aimed at, to counteract the chilling effect of cold walls, which take a considerable time to warm up. The margin added, therefore, should be not less than 20 per cent.

Electric Rating. The heat losses having been determined, the required electric rating in kilowatts may be found from the relationship given in page 351 under the heading Electricity. This expression assumes 100 per cent. efficiency, which will be the case if the heater is in the room it is warming. If, by chance, it is outside, some of the heat may be wasted. In this case 1 kW. = 3,415 × U B.Th.Us. where U is the percentage of heat produced entering the room, expressed as a decimal. For checking calculations to prevent gross errors, and for the purposes of preliminary estimates, the figures here given may be used. They apply to rooms of normal brick construction, having an average amount of glass surface, of normal exposure and of content between 1,000 and 3,000 cu. ft. For rooms having one outside wall allow ¾ watt per cu. ft.; two outside walls, 1¼ watt per cu. ft.; and three outside walls, 1½ or 1¾ watts per cu. ft. Large glass areas and small rooms will require a bigger allowance per cu. ft. The figures also apply to continuous use, and not to cases where rooms may be used only once a week.



HEATING: BY ELECTRICITY. Fig. 1. Cross-section of convector recessed in a wall: air enters through lower louvred grille, is guided by deflectors, heated by element with vertical ribs, and leaves by upper grille.

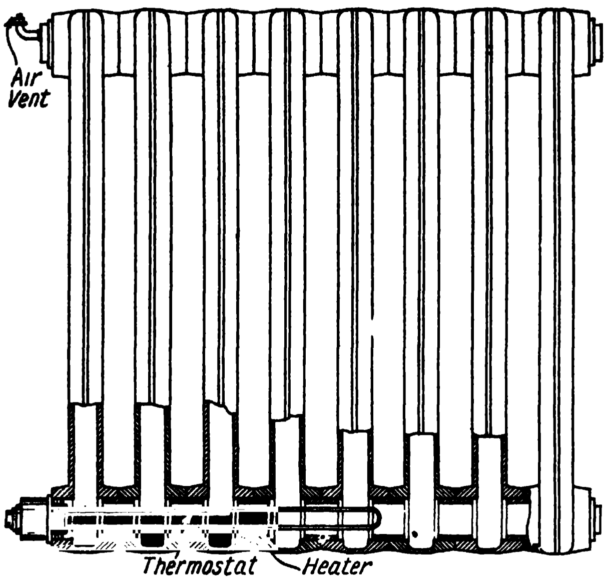
TYPES OF HEATER

Local electric heaters are of many different types. High-temperature radiant heaters are the best known, since most electric fires come under this heading (*see* Fire, Electric). They are characterized by elements running at a high temperature, so that practically all the heat is intense radiation. In addition to fires, panel heaters of this type are made running at a surface temperature of about 400° F. (*See* Panel Heater, Electric *and* Radiant Heating.) The next class is low-temperature radiant heaters or panels having an average surface temperature up to about 200° F. Flush type panels are made in heights of 12 in., 18 in., 24 in. and 30 in., with lengths of 2 ft. to 8 ft. The smallest size has a loading of 400 watts and the largest 2,000 watts, giving heat outputs of 1,360 B.Th.U. and 6,800 B.Th.U. respectively.

Convection Heaters. Following radiant heaters come natural convection heaters, which include convectors, hot water radiators fitted with immersion heaters, and tubular heaters. A section through a typical convector for use recessed in a wall is given in Fig. 1. The heating element is made with vertical ribs between which the air can circulate. Included in the element is a resistance

wire heater on a porcelain former which keeps the whole element hot. When used purely as a heater, the fresh air inlet is omitted. Room air then enters through the bottom grille and is discharged through the top grille, being guided by the deflectors. These also act as heat insulators, the induced air current created by the natural convection currents assisting in this. When ventilation is desired the back inlet is employed. By adjustment of the damper shown entirely fresh air, entirely room air, or any desired mixture of the two, may be allowed to flow through the heater.

It will be seen from the illustration that a thermostat is fitted near the bottom of the convector. It is thus influenced by the room air, which is what is required. The particular heater shown may be obtained in 1 kW and 2 kW ratings, the volume of air handled per kilowatt being 2,600 cu. ft. The resulting temperature rise is 60° to 70° F. If the convector is used for ventilating in cold weather, not all the heat is available for warming. If the outside temperature is 40° F. the exit air temperature from the convector will be about 40 + 60 to 70 = 100° to 110° F. or, say, 105° F. If the room is to be maintained at 60° F., heat will be available by the air cooling down to this temperature, a drop of 105°–60° = 45° F. The heat useful for warming the room is only 45/65 of the total heat output. The rest is wasted in warming the incoming cold air to room temperature. A 1 kW heater used for ventilation with no re-circulation, the outside temperature being 30° F. and the inside 60° F., would have a useful heating effect of $3{,}415 \times \frac{95-60}{65} = 1{,}840$ B.Th.U.



HEATING: BY ELECTRICITY. Fig. 2. Radiator with immersion heater and thermostat control. The loops are partially filled with water, and have an air vent at the top.

Radiators. Electrically heated hot water radiators are normal hot water radiators partially filled with water and with an immersion heater in the bottom nipple-way, as shown in Fig. 2. The usual ratings are 1, 1½ and 2 kW. According to the heating surface of the radiator in proportion to the power of the heater, so will the surface temperature vary. The usual type has a heating surface of about 24 sq. ft. per kW, giving a surface temperature of about 150° F. Other types are made with a surface temperature of about 250° F. *See also* the article on Radiator.

Tubular Heaters. These consist of metallic tubes in which are enclosed resistance wire elements carried on spacers. The usual diameter of tube is 2 in., and the loadings vary from 20 watts to 100 watts per foot run, giving surface temperatures of about 75° F. to about 300° F. These temperatures assume a natural unhindered air circulation over the tubes. If the air circulation is hindered the temperature may rise to a dangerous level. This applies to any convective type heater, and with complete stopping of the air circulation they will probably burn out.

Unit Heaters. Forced - convection heaters are usually known as unit heaters, and are similar in appearance to Fig 3. They consist of a heating element through which air is blown by propellor-type fan. The fan and heater are enclosed in a sheet steel casing fitted on the discharge side with adjustable louvres to deflect the air stream. They are usually suspended at high level, the casing carrying eye bolts or straps for this purpose. The heating element is usually spirals of resistance wire, although occasionally a gilled-tube hot water heater fitted with an immersion heater is used.

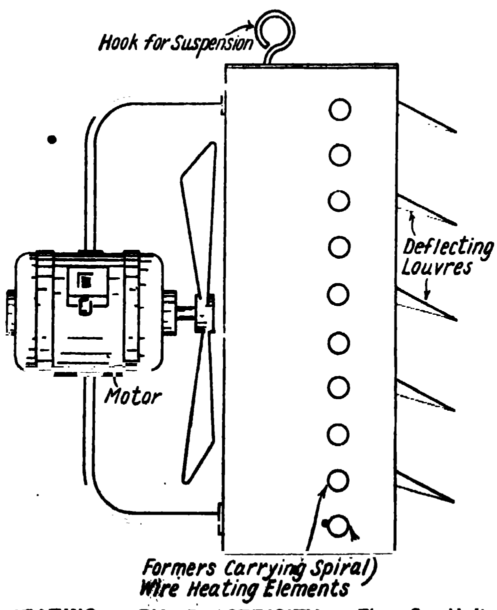
Effect of Paint on Heaters. Unless a heater is received from the manufacturers with a plated or similar finish, it must be painted. Convectors running a low temperature may have almost any paint. To provide for occasions when the temperature may rise owing to defective air circulation, it is better to employ a definitely heat-resisting paint enamel. Low temperature radiant heaters also may be finished with any normal paint.

In this case, however, metallic paints must not be used under any circumstances, since they block radiant heat and may reduce the amount of heat radiated by up to 50 per cent.

Wall-paper or plastic paint will have no deleterious effect, and by their use low temperature radiant panels may be made almost indistinguishable from the wall surface. High temperature panels can only receive the manufacturer's finish. *See further* under the heading Radiation.

SELECTION AND PLACING OF HEATERS

Although the selection may be made on the basis of heat loss and heat output, electric heaters must be properly distributed to ensure satisfaction. Certain types also are more suited for particular uses. High temperature radiant heaters find their application for individual warming. This is essentially so, since it is almost impossible to obtain an evenly distributed temperature with them. People sitting in front of an electric fire may be quite comfortable at comparatively low air temperatures. For this reason radiant panels are employed in such places as open-air schools. They are preferably placed at high level so that the rays of heat shine on scholars. Several fixing positions are given in Fig. 4 (p. 520). (*See also* Schools: Heating).



HEATING: BY ELECTRICITY. Fig. 3. Unit heater or forced-convection heater in which air is blown through heating element by fan.

Panels may also be used for local warming in factories where it would be uneconomical to heat large spaces for the sake of isolated workers. Here the general temperature may be kept comparatively low, with individual panels for each worker. It must be remembered always that radiant heat travels in straight lines. The panel must, therefore, be positioned so the rays from its face may shine uninterruptedly on the people to be warmed.

Low temperature radiant panels may be used in situations mentioned above. They may also be employed for general room warming, the choice between them and convectors being one of preference or cost. They have the disadvantage that they must not be obscured by any solid body. For this reason they are often fixed on ceilings.

There is a tendency to regard radiant heating as more healthy and economical. It is found that the human body is comfortable with lower air temperature when warmed by radiant heat than when the heat is convective. The lower air temperature results in smaller heat losses and reduces running costs. For this reason heat losses are often calculated for $\frac{1}{4}$ to $\frac{1}{2}$ air change per hour when radiant heating is used, instead of the usual 1 to 3 air changes per hour. If this is done a temperature guarantee cannot be given. Further information on this aspect will be found under Radiant Heating.

Placing of Heaters. In regard to the placing of heaters, two general principles should be followed. First, draughts should be prevented; secondly, the temperature through the room should be even. The first means that heaters should be placed generally under windows. If doors open to the outer air, as in shops, heaters should be placed near them. Where skylights exist, particularly if they are large, down-draught should be prevented by tubular heaters under them. To comply with the second principle, heaters should

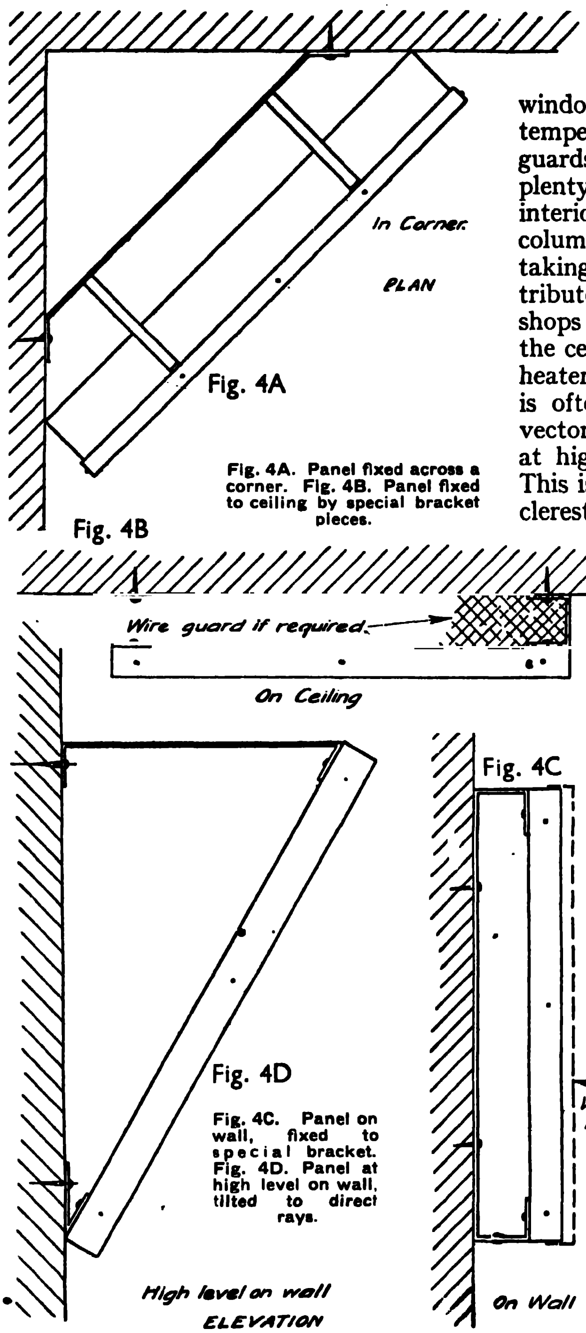


Fig. 4A. Panel fixed across a corner. Fig. 4B. Panel fixed to ceiling by special bracket pieces.

Fig. 4C. Panel on wall, fixed to special bracket. Fig. 4D. Panel at high level on wall, tilted to direct rays.

HEATING : BY ELECTRICITY. Fig. 4A, B, C, D. Fixing positions for radiant panels, preferably at high levels.

not be more than 15 ft. apart on an outside wall. Also, if a room is more than 20 ft. wide, at least one heater should be placed on the inside wall opposite the outside wall.

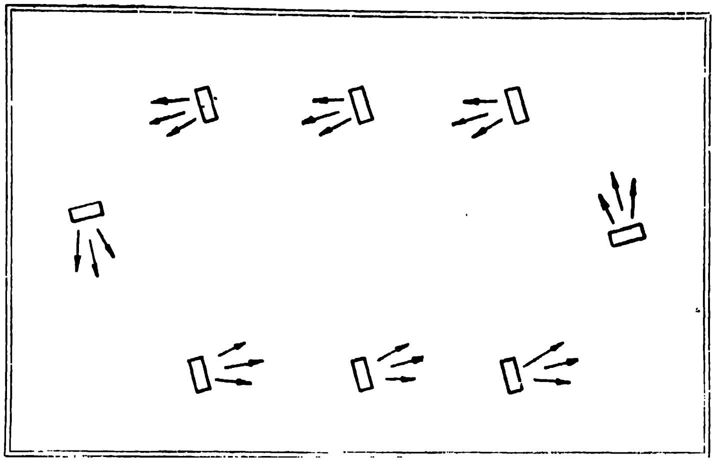
School classrooms may be effectively warmed by tubular heaters round the rooms, giving an even distribution of heat. Additional heating surface should be placed under the windows. Tubes having a low surface temperature should be used, otherwise guards may be necessary. Shops require plenty of heat at the entrances. The interior may be warmed by heaters on columns or at the end of showcases, taking care that the heat is well distributed. Alternatively, classrooms and shops are often warmed by panels at the ceiling. Churches may have tubular heaters at low level on the walls, since it is often difficult to find room for convectors. Some tubes should be fixed at high level to prevent down-draughts. This is particularly important if there are clerestory windows.

It is often impossible to fix heaters near the floor in factories and garages, and tubular heaters at high level may be used in such circumstances. This is not the best method, however, since tubular heaters produce a high temperature under the roof and consequent waste of heat. In addition it is some time before the heat filters down to the working plane. The better method is the use of unit heaters. These blow the warm air down where it is needed and the roof temperature should not be excessive. The heat is felt immediately the units are switched on, and in summer the fans may be run without the elements being hot, circulating the air with beneficial results.

The unit heaters are best arranged as in Fig. 5 (p. 521), so that continuous circulation of warm air is produced. Depending on the air velocity, one unit heater can warm equably a considerable floor area. It is best, however, to allow one heater to deal with not more than about 1,000 sq. ft. floor area unless they can be mounted very high up. The heaters should be wired in such a manner that they are cut out if the supply to fan is switched off.

Automatic Heat Control. Electric heating should always be thermostatically controlled. This adds to the first cost, but

the addition is quickly saved in running costs, since electricity is a comparatively expensive method of heating. Convectors often have their own thermostats. If not, each room should have an independent thermostat, though this need not control all the heaters in the room. If, say, half are controlled, cheaper thermostats may be possible and the uncontrolled heaters will normally be required so long as any heat is necessary. The thermostat should be fixed about 4 ft. to 5 ft. above the floor. It should not be adjacent to a heater, window or door, but be in a position likely to be at a temperature equal to the average room temperature. Where large currents are required it will often be necessary to use a relay and contactor in conjunction with the thermostat. The thermostat then actuates the contactor, which carries the main current, by means of the relay.



HEATING: BY ELECTRICITY. Fig. 5. Unit heaters in factory: placed at high level and at the correct angles to ensure continuous circulation of heated air from one unit towards the next. (*Compare* arrangement of unit heaters in hot water circulation system in factory, shown in Fig. 6, p. 389.)

Central Heating. When electricity is applied to an existing hot water heating installation a central boiler is required, which may be a cylinder containing the proper number of immersion heaters. This is exactly similar to a hot water supply installation, and information will be found under Immersion Heaters. For larger installations electrode boilers are used. These consist of two or more electrodes immersed in the boiler. Current flows from one electrode to the other through the water, warming it in the process. Electrode boilers generally use a high electrical pressure, and their treatment is a specialist's matter.

HEATING: (5) BY GAS

By J. Murray Grammer, Assoc.M.Inst. Gas E., A.M.I.H.V.E.

In warming rooms or buildings by means of gas appliances the same general considerations are involved as with other methods of heating, and these are set out in the first article of the present Group, by Mr. Fretwell. For Gas Fires, Air-Heaters and Convectors, *see* under the heading Gas Fires, where detailed information is given. In the present contribution the characteristics of the principal warming appliances are summarized. See *also* Panel Heater; Radiator (Gas).

Gas fires give immediate comfort at an air temperature not less than 50° F., provided that the occupants receive the heat at a suitable intensity. They were originally considered best suited for intermittent use, as they are more expensive to run than flueless appliances (although the ventilating effect of a flued fire must not be overlooked). On two-part tariff rates, however, they are cheaper to run than coal fires, even over quite long periods.

Convector gas fires demand an air temperature of 55–60° F. to give immediate comfort results, owing to the lower radiant intensity; the overall efficiency is higher, as provision is made in the design for air to pass over and through the fire in the room, thereby providing extra convected heat. The combination of a gas fire and a flueless appliance gives a somewhat similar effect to that of a convector gas fire, but the products of combustion are not removed completely from the room if the separate heaters are used. (Gas fires are dealt with under their own heading in this work.)

Flueless Appliances. These have the highest overall efficiency and are suitable for continuous and general heating, but have the main disadvantage of lacking positive ventilation. Bowl heaters provide comfort from radiant heat when the occupants can be fairly near to the heater, an air temperature of 55–60° F. being required.

It must be remembered that where gas lighting is in use, it can supplement the main forms of heating. A considerable amount of heat is given out, so that normal gas lighting will reduce the main heating load of a room by 10–50 per cent. according to the type of lighting adopted and the kind of room.

Flueless radiators are admirable for lower air temperatures than those required in living rooms—*e.g.* in halls, corridors and shops or to supplement radiant heaters in cold weather.

Central Heating. Central heating by gas is in its effect no different from central heating using any other type of fuel in the boiler, with the exception that owing to the ease of control and flexibility of a gas system, comfort conditions are more readily maintained by its employment, and fuel and labour are saved.

Air Heating. Air warming by remote or local gas-fired heaters is a branch of heating to which gas as a fuel can easily be adapted. All the heat is convected, and generally the firing is by indirect methods. A typical air heater for a Turkish bath installation consists of finned vertical tubes (baffled inside), up and through which the hot flue gases flow, while air is passed over the tubes by a fan and is so heated. When the appliance is designed for use in drying chambers, the flue gases are often allowed to mix with the air to be heated.

Unit heaters consist of vertical tubes, heated internally by hot flue gases, over which air is passed from a propellor fan. They are entirely automatic, as the air pressure controls the opening of the gas burner. Unit heaters may be suspended from the ceiling of a workshop, and the air heated and circulated round in one direction (being, as it were, passed on from heater to heater). These heaters generally carry separate flue pipes.

Panel Heaters (*which see*). These are another type of gas warming appliance, giving a radiant output. These work at a high temperature and have a radiant efficiency of about 40 per cent. Two models are illustrated under the heading referred to above. In factories and similar buildings panel heaters are of especial value and are fixed overhead. They are also employed out of doors (*e.g.* for an open air school, etc.).

Temperature Control. On the question of controls the most important is the room heat detector or thermostat. For a fire, or a few radiators, the remote detector and small copper communicating pipe to the relay valve provide the most reliable and cheapest system to install. With bigger systems, electrical controls (*e.g.* motorized valves) are becoming more popular. Several methods of automatic ignition are now in use which eliminate the stooping around with matches, so long associated with the lighting of gas fires. (*See* Gas Fire.)

Other advantages claimed for gas, apart from those mentioned above of easy thermostatic control and easy ignition, are flexibility (heat is available or can be discontinued almost immediately); heat output can be maintained constantly or regulated to any desired output; with many appliances positive room ventilation is assured; high temperature radiant heaters (gas fires) provide an attractive appearance; there is small possibility of a breakdown in supply.

Running Costs. On the question of costs, a flueless gas fire is about half as expensive, heat for heat, as a proper gas fire, but the gas fire is often much more useful in that it provides radiant heat—ensuring comfort in comparatively low air temperatures.

At usual prices a flued gas fire is cheaper than, or as cheap as, a coal fire for heating up to a period of nearly 3 hours' use. In use over a period of 8 hours, the flueless gas fire is as cheap as a coal fire; and the convector gas fire for a period of about 6 hours. For warming a room of about 1,500 cu. ft. capacity, in use for 8 hours, the following comparative costs may be stated: coal fire, 5½d.; gas fire (8·7d. per therm), 8½d.; gas fire on two-part tariff rate at 4d. per therm, 4d.

For industrial air heating and central heating, the usual heating calculations for fuel required would have to be made, but most gas companies offer special tariffs to consumers for this type of duty.

HEATING: (6) COMBINED CENTRAL HEATING AND HOT WATER SUPPLY

By Louis J. Overton, M.I.H.V.E.

Here the merits of the combined system are discussed with practical hints on layout and installation. An example is given of a domestic installation, where two radiators are served from the hot water supply boiler on the indirect system. Details and data are given also for a larger installation with seven radiators and a calorifier. Alternative apparatus for summer use is dealt with in the final section. *See under the heading* **Boiler**: *also* **Calorifier**; **Hot Water Supply.**

Large installations of central heating and hot water supply have at times been made on combined systems direct from boilers or calorifiers, the same main and branch pipes feeding both radiators for heating and draw-off taps for hot water supply. The economy claimed for such schemes is that there is only one set of pipe circulations instead of two; and the heat emission from piping being less, fuel consumption is reduced.

There are, however, certain objections to direct systems of combined heating and hot water supply, and these may be stated as follows:

(*a*) Water drawn off at taps, and the consequent influx of cold water is sure to reduce the temperature of the radiators and their heat emission.

(*b*) Water drawn off at taps will affect the circulation of water through the radiators, as both the flow and return pipes of a circulation can become temporary supply pipes to a draw-off point when opened.

(*c*) Water drawn off and new water admitted to a circulation causes more air to be freed, and this accumulates in radiators, which have to be vented.

(*d*) When radiators or circulations to radiators are shut off by valves for a period, internal corrosion takes place; and when valves are eventually opened the hot water supply shows evidence of the rust.

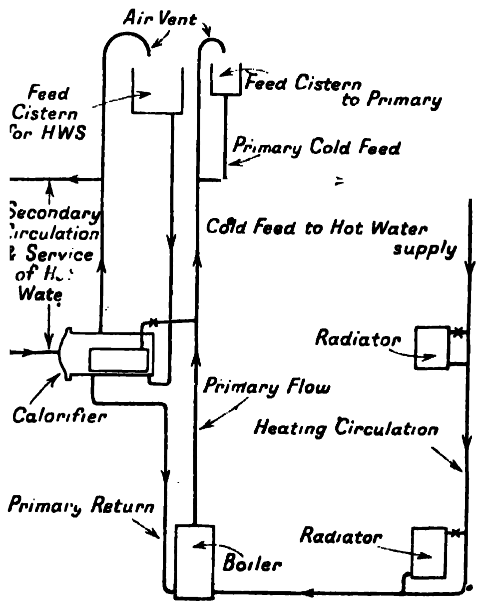
(*e*) Although only one set of main and branch pipes is required instead of two, pipes will have to be of larger diameter in order to serve both heating and hot water supply.

It is a common practice to serve towel rails and sometimes one or even two radiators from an ordinary direct hot water supply system, and in all cases a hot water supply type of boiler must be used which can easily be cleaned out.

The Indirect System. The best method of dealing with a combined central heating and hot water supply is to install an Indirect System, in which the water of the primary circulation, inner cylinder or coil of the calorifier, radiators, and heating circulation never come into contact or mingle with the water in the outer cylinder of the calorifier or service pipes to the draw-off points. Such being the case, separate feed cisterns and cold feed pipes are necessary.

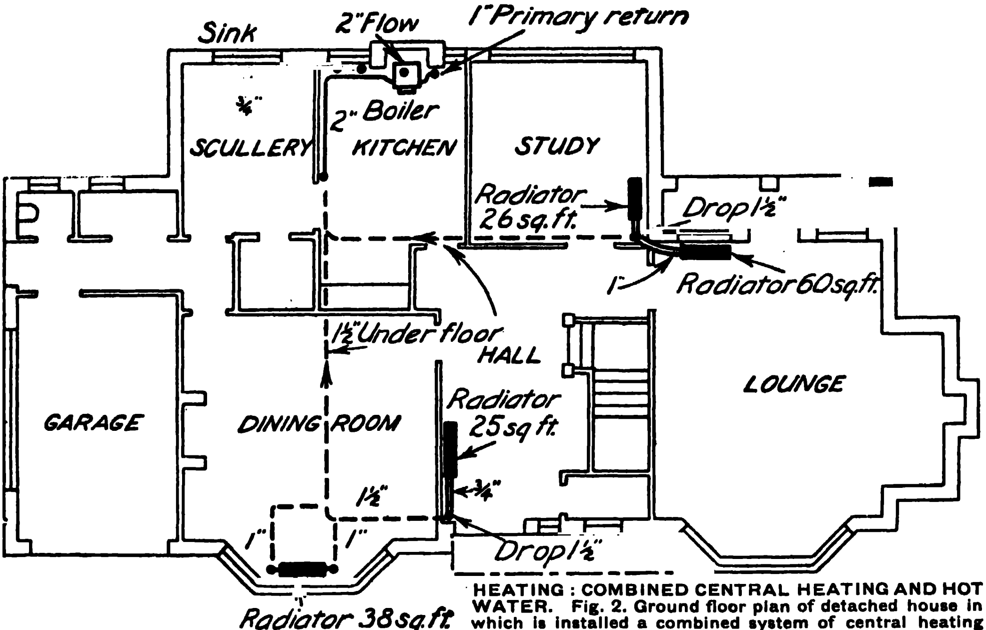
One combined feed and expansion cistern is connected to the primary circulation, or into the bottom of the boiler, while the cold water cistern supplying the hot water service is connected to bottom of outer cylinder of calorifier.

Such an indirect system of hot water supply with a heating circulation serving radiators is illustrated by Fig. 1. This shows two radiators served from the primary circulation on a dropping single-



HEATING: COMBINED CENTRAL HEATING AND HOT WATER. Fig. 1. Central heating by dropping single-pipe system: pipes taken to radiators taken from primary circulation. Indirect hot water supply by calorifier.

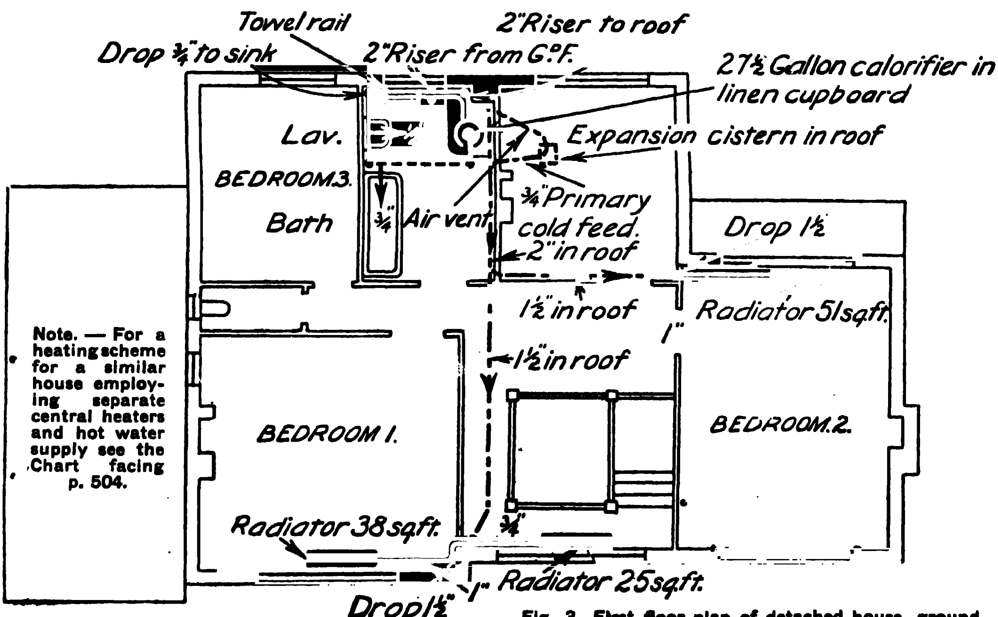
pipe system—one radiator at a high level and the other at the same level as the boiler. Cooling water in radiator at high level actually accelerates circulation around this branch of the primary circuit and through radiator at the low level.



HEATING: COMBINED CENTRAL HEATING AND HOT WATER. Fig. 2. Ground floor plan of detached house in which is installed a combined system of central heating (serving seven radiators) and an indirect hot water supply with calorifier (see *also* Figs. 1 and 3).

Typical House System. As a further example on a larger scale, assume that a house, as illustrated by Figs. 2 and 3, is to be provided with a combined system of central heating and hot water supply. Radiators are to be placed in the ground floor rooms and staircase hall; also on the landing and in the two principal bedrooms on first floor.

The subject is approached at the moment from the point of view of central heating, with the intention of insuring conditions of comfort in the rooms to be warmed without dependence upon fires or other heating contrivances. It is advisable to calculate the heat requirements on the basis of obtaining a temperature of 60° F. in each room dealt with when the



Note.—For a heating scheme for a similar house employing separate central heaters and hot water supply see the Chart facing p. 504.

Fig. 3. First floor plan of detached house, ground floor being shown in Fig. 2, served by combined system of central heating and indirect hot water supply.

outside temperature is 30° F., allowing for one change of air per hour. Assume that these calculations have been made, and have resulted in the following figures for heating surfaces of radiators to be allocated to the various rooms:

	sq. ft.
Ground Floor:	
Dining room	38
Lounge	60
Study	26
Hall	25
First Floor:	
Bedroom 1	38
Bedroom 2	51
Landing	25

The points at which hot water is to be provided are: one bath, one lavatory basin, and one sink; also a circulation through a towel rail in bathroom. With a combined system of central heating and hot water supply from one boiler, it is evident that the greater part of the boiler capacity will be devoted to the central heating; and that during warm weather when the hot water service only is required, care will have to be taken to keep the boiler fire well under control. For such control an automatic damper regulator should be fitted to the boiler.

In the house system described there are seven radiators, together with the necessary circulation pipes, so that it would be wrong to use a direct hot water supply system from the same boiler that serves the radiators. Therefore, a calorifier (*which see*) or indirect cylinder should be provided for the hot water service. The indirect cylinder might be placed on brackets overhead in the kitchen, but as there is, in this case, a linen cupboard in the bathroom on the first floor, it could be used to accommodate the cylinder, which would then serve to warm the linen cupboard.

This arrangement of combined central heating and hot water supply is shown on the ground and first floor plans, Figs. 2 and 3.

Boiler and Heating Layout. A sectional-type heating boiler is placed in the kitchen, and a 2-in. diameter primary flow pipe is carried direct to the roof space, where it is vented at the top over a 10-gal. feed cistern which supplies the primary circulation only. A ¾-in. cold feed connexion from the cistern enters the falling primary flow on its way to the radiators. A 1-in. diameter flow connexion is taken from the rising primary flow to the inner cylinder of the calorifier in the linen cupboard on the first floor, and the primary return from the inner cylinder drops in 1-in. diameter piping direct to the boiler, a valve being provided so that the circulation to calorifier may be regulated. Flow and return connexions of ¾-in. diameter are taken from the primary circulation before it reaches the calorifier, to serve a towel rail placed in the bathroom.

After the 2-in. diameter primary circulation in the roof space has been vented it slopes downward, taking the ¾-in. cold feed connexion. It then divides into two 1½-in. diameter circulations, one dropping in the corner of bedroom No. 4, feeding one radiator in bedroom No. 2; after which it drops in corner of study, serving one radiator in the lounge and one radiator in the study.

The other 1½-in. diameter circulation drops in corner of landing, feeding one radiator in bedroom No. 1 and one radiator on landing; after which it drops in corner of entrance hall, feeding one radiator in hall and one radiator in dining-room. The two 1½-in. diameter circulations return below the floor, joining into a 2-in. diameter main return to the boiler in kitchen.

The connexions to the radiators should be taken straight in at the top and the returns from the bottom, thus allowing the radiators to vent automatically and obtaining the full benefit of the extra circulating pressure through the water cooling in the radiators.

Connecting pipes to radiators of 38 sq. ft. and over should be 1-in. diameter, and those below 38 sq. ft. should be ¾-in. diameter.

Hot Water Supply. The draw-off points in the hot water service are so near to the calorifier that a connexion may be taken from the expansion pipe leaving the top of the cylinder; and direct connexions may be run to the bath and lavatory basin, afterward dropping to the sink in scullery. The cold water connexion for the hot water service should be at least ¾-in. diameter, entering the outer cylinder of the calorifier near the bottom. This cold water supply must be from a cold storage cistern, and not from the combined feed and expansion cistern which serves the primary and radiator circulations.

For the hot water service a calorifier with a capacity for heating and storing 27½ gal. of water per hour will be ample.

Boiler Capacity. The power of the boiler to be used can be computed as follows:

Heating:	Heating surface	Coefficient	=B.Th.U.
Radiators	263 sq. ft.	× 160	42,080
2 in. diameter piping ..	20 ft.	× 129	2,580
1½ in. „ „	70 ft.	× 105	7,350
1 in. „ „	70 ft.	× 93	6,510
¾ in. „ „	30 ft.	× 62	1,860
Covered piping			
2 in. diameter piping ..	20 ft.	× 52	1,040
1½ in. „ „ ..	48 ft.	× 42	2,016
			63,436
Hot Water Supply:			
27½ gallons raised 100° F.	27,500 B.Th.U. for heating boiler rated at		17,500
[NOTE —For explanation of coefficients *see under* the heading Calorifier.]			80,936

A suitable boiler would be one having a heating rating of 90,400 B.Th.U per hour.

All return pipes carried below the floor should be well covered with non-conducting composition.

For calculations of heating surface etc. *see* Hot Water Supply: (2).

Alternative Apparatus for Summer Use. As boiler capacity is very high on account of the large number of radiators served, it would be a great advantage to provide alternative means of hot water supply when no heating is required. This could be accomplished by installing a small gas-fired boiler with flow and return pipes interconnected with the primary circulation to calorifier; *see* Boiler: (7).

Another excellent method is to have an electric immersion heater inserted in the hot-water storage outer cylinder of the calorifier, with automatic cut-out which would break electric connexion when the storage water reached a defined temperature.

Either of these appliances would be immediately available in warm weather when not desirable to work the boiler.

HEAT LOSS AND HEAT REQUIREMENTS OF A BUILDING

By Louis J. Overton, M.I.H.V.E.

On the accompanying Chart are given the heat loss coefficients for the principal building materials and also for partitions, doors, floors and roofs. Methods of calculating heat-loss are described in the text, with examples. *See also* Chart under Heating : (2) facing page 504.

The heat required to maintain a definite air temperature inside the room of a building when the air outside is at a certain temperature may easily be calculated, and when the result is obtained on the basis of B.Th.U. per hour there is no difficulty in selecting the heat transmitting appliances suitable for giving that required amount of heat.

There is no excuse for mere rule-of-thumb methods or guess-work in estimating heat requirements or the application of heating apparatus suitable to the work to be performed, as, with the coefficients and data available, calculations can be made which enable a satisfactory result to be assured.

Whatever means are eventually to be adopted for warming the rooms of a building, the method of determining the amount of heat required is exactly the same, and consists of calculating first the heat required per hour to warm, the cubic feet of air, plus any additional air admitted for ventilation purposes. The amount of fresh air admitted to a room is generally expressed as air changes per hour, and the coefficient generally used is ·02 B.Th.U., because:

·02 B.Th.U. will raise 1 cu. ft. of air 1° F.

Example. Assume a room 12 ft. × 10 ft. × 10 ft. high has to be warmed to 60° F. when the temperature outside is 30° F.

and allowance has to be made for two air changes per hour; then:

12 × 10 × 10 = 1,200 cu. ft.
1,200 cu. ft. × 2 changes × ·02 × (60–30) = 1,440 B.Th.U per hour.

Heat Losses. Warming the air in a room is, however, not the only consideration, for additional heat must be provided to compensate for warmth which is continually passing through

the structure of a building. The amount of heat thus lost depends upon the conductivity of the building material and the difference in temperature between the inside and outside air.

Coefficients of heat loss through building materials have been obtained by experiments, tests and research work in many countries, and the results compared are so similar that the differences are unimportant.

These coefficients are termed the values of *U*, and represent the amount of heat in B.Th.U. per hour which will pass through 1 sq. ft. of structure per degree F. difference in air temperature between inside and outside of a room in a building.

The tables in the Chart facing this page give a list of ordinary heat loss coefficients gleaned from various sources. They include values for walls of all descriptions; boards and sheets, partitions; glass; doors; roofs and floors. Since the aspect considerably influences heat loss, a note is given for suggested allowances for special conditions.

Example. Assume the room 12 ft. × 10 ft. × 10 ft. has to be warmed to 60° F. when 30° F. outside, allowing for two air changes per hour.

		sq. ft.
There is a window 6 ft. × 5 ft. ..	=	30
Area of exposed 9-in. brick wall, plastered inside	=	190
Ceiling with slates on boards over ..	=	120
Floor boards on joists with air space under	=	120

The heat requirements per hour can (with the coefficients available) now be calculated in the following manner:

					B Th.U.*
Air	1,200 cu. ft. × 2	× ·02	..	=	48
Window	30 sq. ft.	× 1·03		=	30·9
Walls	190 „ „	× ·33		=	62·7
Ceiling	120 „ „	× ·17		=	20·4
Floor	120 „ „	× ·05		=	6
	* Per ° F. difference.				168

168 × 30 deg. F. difference = 5,040 B.Th.U. per hour.

[The I.H.V.E. booklet on heat loss may be consulted.]

For further practical examples *see* Heat: Modern Theory; *and* Heating: (1).

RESEARCH ON HEAT REQUIREMENTS

The heating of dwellings has been the subject of prolonged research. A report by the Heating and Ventilation (Reconstruction) Committee of the Building Research Board of the Department of Scientific and Industrial Research was published in 1945 by H.M. Stationery Office as No. 19 of the "Post-War Building Studies." It deals with all methods and appliances for providing heat for warming, hot-water supply, cooking and laundry-work used in dwelling houses in Gt. Britain.

The annual heat consumption per person is shown to be higher in this country than in Germany; and in the United States of America the standard of heating is higher, although the heat consumption is scarcely greater.

Some sections of the Report deal with the amount of heat required in dwellings, and useful coefficients of heat loss through uncommon building materials are given which are not to be found in other publications. Attention is drawn to the importance of effective insulation of hot-water pipes not serving for heat emission and also to the insulation of building structures to conserve fuel consumption. The heating efficiency and economic use of coal and other fuels is also very thoroughly dealt with.

So many points of view are expressed and the methods of using the different types of fuel and appliances are so varied that it is almost impossible to reach any definite conclusion as to their respective merits, but some of the most interesting items of information given are summarised.

It is possible to have too much comfort, for the body may then lose its power of quick adaptation which is an essential requirement for normal health. For the most part, outside workers are exposed to conditions in which the body has to adjust itself to temperature changes. What is essential is that persons can be warm and cosy when they need to relax. There is a minimum standard of heating and ventilation below which health would suffer.

Desirable Warmth in Rooms. In living-rooms an equivalent temperature of about 65 deg. F. has generally been considered as a suitable standard for this country for warmth when sitting for lengthy periods. Variations in range recommended are:

General	60°—68° F.
Active Housework	50°—55° F.
During night	45°—50° F.
Bedrooms: Dressing	50°—55° F.
Bedrooms: During night	45°—50° F.

Statistics showed that during February and March one room only was heated in

about 74 per cent of all the houses canvassed, two rooms in 23 per cent and three rooms in 3 per cent. The bedrooms were not warmed in nearly 87 per cent.

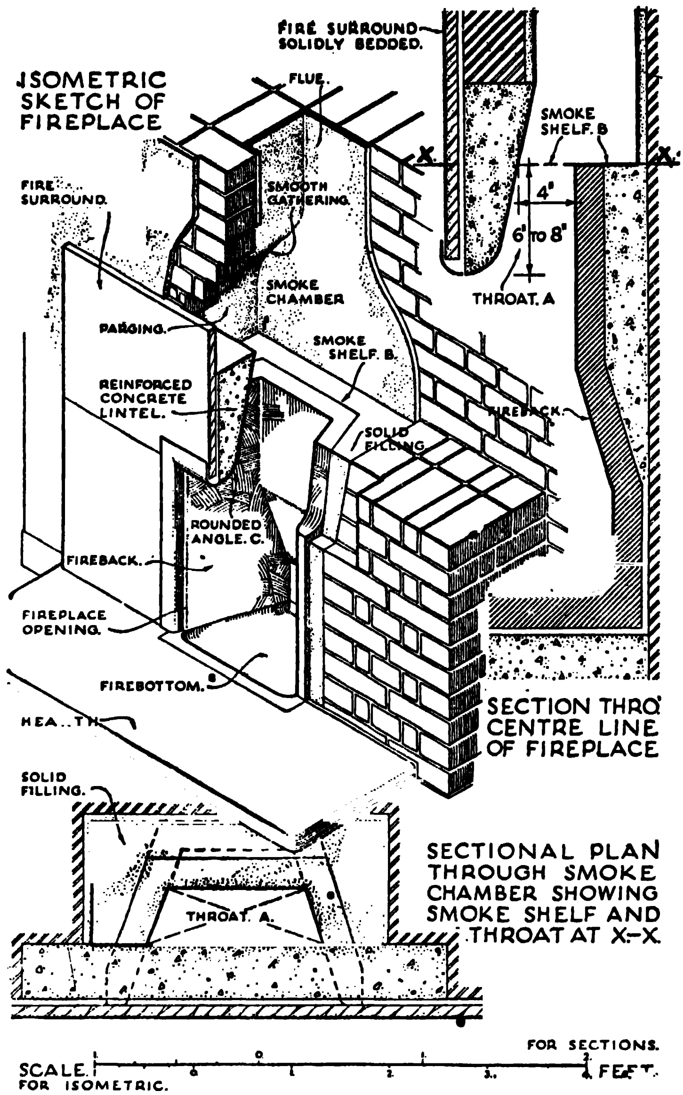
High Temperature Radiant Heating. When high temperature radiant sources are used, such as open fire, gas fire, or luminous electric heaters, it has been found that people were fairly comfortable with air temperature of 55 deg. F., provided that sufficient radiation was felt.

Ceiling heating should not be used as the sole source of heat in rooms much less than 12 ft. high.

Hot Water Supply and Cooking. For a family of four persons it is estimated that 250 gallons of water at 140 deg. F. should be provided weekly. For America, an estimate of from 175 to 290 gallons weekly per house at 140 deg. F. to 180 deg. F. is considered normal.

For cooking the heat required is estimated at 50,000 to 150,000 B.Th.U. per week for a family of four.

Heating Efficiency and Design. The following note from the "Building Studies" No. 19 Report is of practical importance.



Modern design for open fireplace and chimney. From "Building Studies" No. 19 of 1945, a report of the Heating (Reconstruction) Committee of the Building Research Board. *For* M. O. W. complete heat prefabricated unit see Plate *f. p.* 812. *By permission of the Ministry of Works*

"The performance of any appliance in which combustion takes place is very much affected by the chimney to which it is connected. Solid-fuel appliances rely on chimney draught to pull air for combustion through the fire or boiler. The intensity of this draught depends on the height of the chimney. Draught is likely to be erratic with low chimneys, where they are particularly subject to the influence of wind. To ensure satisfaction a chimney should terminate at least 2 ft. above the ridge of the roof which it penetrates and not less than 2 ft. above the ridge of any roof within 10 ft. of it. A chimney considerably higher than necessary makes difficult the proper control of air-flow through a boiler by means of its dampers. In such cases an additional flue damper or automatic draught-regulator should be used to limit the maximum draught exerted on the boiler. Individual appliances should each have their own flue, which should preferably be on an inside wall. Adequate cleaning facilities (soot doors) should be provided and the walls of the chimney should be air-tight.

"The interior surfaces of chimneys should be smooth and of fire-resisting construction; sharp bends, sudden changes of cross-section, and pockets should be avoided. The throat of a chimney connected to an open fire is particularly important and should be constructed in accordance with the diagram." (*See* diagram.)

Fuel Consumption. A table of fuel consumption for space heating and hot-water appliances was issued by the Solid Smokeless Fuels Federation in 1946.

Table A—FUEL CONSUMPTION

Type of Heating Appliance Scheme	Consumption cwt. per week. (solid smokeless fuel)			
	Living Space	*Hot Water*	*Cooking*	*Total*
1. Heating stove with back boiler in living room	1–1¾		Gas or Electricity	1–1¾
2. Convector open fire or heating stove in living room .. .. .. Domestic hot-water boiler	¾–1	¾–1	Ditto	1½–2
3. Heating stove with back boiler in kitchen Heating stove or convector open fire for use in evenings in living room	1–1¼ (kitchen); ½ (living room)		Ditto	1½–1¾
4. Convector open fire or heating stove in living room .. .. .. Cooking range with back boiler	¾	1¼–1¾		2–2½
5. Back-to-back range with heating stove, cooker with hot-water boiler and convection heating	2–2¼		•	2–2¼
6. Heating stove with back boiler for heating 2 or 4 radiators .. Hot-water boiler ..	1¼–1¾	¾	Gas or Electricity	2–2½

The minimum figures shown are for a modern house (950 sq. ft. total area) efficiently heat-insulated and• with the hot-water storage cylinder insulated according to the British Standard. Maximum figures apply to larger houses (up to 1,500 sq. ft. floor area) or smaller houses not of modern heat-insulated construction.

Coal and Smoke. Half the pollution of the atmosphere by smoke is attributed to domestic heating and half to railways and industries.

In the year 1938 there were 12·5 million dwellings with about 3·7 persons to each. Coal used for heating and cooking was about 63,000,000 tons, being about 1½ tons per head. Better insulation would give higher standards of heating without increasing fuel consumption.

Dyestuffs and plastic industries are large users of by-products from coal when used for gas production. When raw coal is burnt directly the by-products are lost (with smokeless combustion they are converted into heat).—*L. J. Overton.*

Research Station Tests. Following the issue of the Report the Building Research Board erected eight experimental houses at the Research Station at Garston to carry out full-scale trials on heat insulation to determine the effect on fuel consumption with varying standards of insulation. Four grades of insulation, *A* to *D*, were employed.

Various materials, as listed in Table *C*, were used to obtain these standards, but it should be emphasised that the choice of any particular material was made as a matter of convenience at the time of building rather than for any reason of special merit of a particular material.

These four houses were all heated in the same way, a small amount of heat being provided throughout the house as " background " heat with topping up in the living rooms at times of normal usage. Two other houses were duplicates of two of the above four, but in addition to the background heating above, the living rooms were heated fully and continuously. The object of this was to compare the fuel consumption between continuous heating and intermittent heating.

The eight experimental houses at Garston, Herts., were used mainly for testing the economy obtained by effective insulation ; l[illegible]r 20 houses were erected at Abbots Langley. This latter group were built with the same degree of insulation, but different systems of heating were installed in 19 of the houses, one system only being repeated in order to test any difference in results between the southern and northern aspects.

Table B—THERMAL TRANSMITTANCE
(B.Th.U./Sq.Ft./Hr./°F.)

Grades of Insulation:	*A*	*B*	*C*	*D*
External walls ..	0·34	0·25	0·20	0·15
„ living room	0·34	0·20	0·15	0·10
Windows	1·0	1·0	1·0	0·5
„ living room	1·0	1·0	0·5	0·5
Ground floor ..	0·25	0·20	0·15	0·10
Roof and top floor ceiling	0·56	0·30	0·20	0·15

Grade *A* represents the ordinary pre-war houses and Grade *C* the standard recommended by the Committee.

Table C.—MATERIAL AND CONSTRUCTION

Insulation grade	Ground floor	Roof	External walls to living room	Other external walls
A	Joint and board on sleeper walls.	Felt on concrete plaster lining.	11 in. cavity brick, plaster lining.	11 in. cavity brick, plaster lining.
B	Tiles or Grano. on concrete raft.	Felt on 2 in. cement screed on concrete, lining of ½ in. fibre board direct on concrete. No plaster.	4½ in. brick, 2 in. cavity, 4 in. foam slag blocks, plaster.	4½ in. brick, 2 in. cavity, 3 in. clinker blocks, plaster.
C	1 in. wood block on concrete raft.	Felt on 2 in. cement screed on concrete. Lining on 1 in. cork plastered.	6 in. "Invicta" block, rendered externally. Lining of plaster on 1 in. cork.	As L.R. walls but ½ in. cork.
D	1 in. wood block on 1 in. cork on concrete raft.	Felt on cement screed on 3 in. foamed slag on concrete. Lining 1 in. cork plastered.	4½ in. brick, 2 in. cavity. Inner wall of stud partition with internal sheet of plaster board and external sheet of asbestos cement with 3 in. slag wool filling.	As L.R. except layer of aluminium foil substituted for slag wool filling.

NOTE.—Grade *C* house has double windows to the living room.
Grade *D* house has double windows throughout.

The extent of heating provided may be classed under four headings :

1. *Pre-war Standard (5 houses).*

Heat in living rooms but none in bedrooms. Kitchen and dining spaces dependent upon heat from cookers and any domestic hot-water heaters. No heat in entrance halls.

2. *Improved Standard (6 houses).*

Central heating as a background and topping-up heat by means of electric or gas heaters to the living rooms and bedrooms. Halls heated.

3. *Full House Heating (5 houses).*

Provision to warm all rooms, but not essentially continuously.

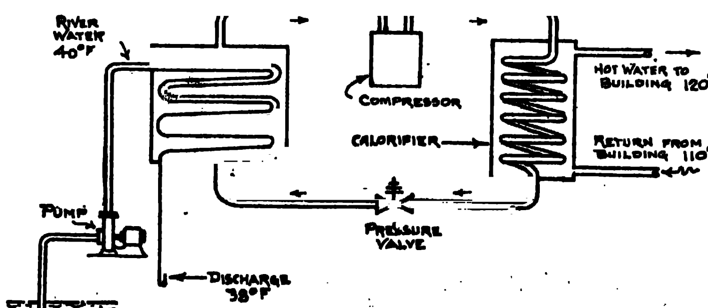
4. *Miscellaneous (4 houses).*

This type with solid fuel cookers in kitchen-living rooms, but one house entirely nondescript.

The Abbots Langley heating tests (1947–1948) were not limited to space heating, but included all forms of fuel consumption. The first Report confirmed that houses insulated according to Building Study No. 19 (p. 527) gave improved conditions. Central heating ("whole house") gave highest efficiency.—*S. G. B. S. and L. J. O.*

HEAT PUMP INSTALLATION. The term Heat Pump is applied to a method of extracting heat from ordinary river or well water, and even from the earth or air, and utilising it for central heating and hot-water supply. One such system has been installed at Norwich by Mr. J. A. Sumner, M.I.Mech.E., City Electrical Engineer.

The action of a heat pump plant is illustrated. Water at 40° F. is pumped from a river, passed through a pipe coil and discharged as finished with at 38° F. The coil is housed in a chamber containing sulphur dioxide which boils at a temperature of



HEAT PUMP. Diagrammatic representation of the principle of operation.

30° F. when under 22 lb. pressure per sq. in., and, in vaporising the sulphur dioxide extracts its latent heat from the water in the coil. The vapour is picked up by a compressor which increases the pressure and temperature of the vapour, which is then delivered through a coil in a second chamber or calorifier containing the water to be heated for central heating or hot-water supply. In this coil the vapour condenses to liquid, giving off its latent heat to the water to be circulated in the building. The liquid of condensation in the coil returns through a pressure-regulating valve to the first chamber, and the process repeats as a cycle of operations.

In the example given, the water to the building flows at 120° F. and returns at 110° F., and, as with a temperature drop of 10° F. only there would be very little circulating pressure due to gravity, a circulating pump would be required.

For working such a plant no expense would be incurred for fuel, solid or liquid, in process of combustion, but there would be the cost of driving the water supply through the coil in the first chamber and the cost of driving the compressor. The cost of driving the pump for circulating hot water in the building would be similar in any system.

In regard to the river water from which heat is abstracted, assuming that the heat required for the building is 800,000 B.Th.U. per hour and the water temperature is lowered from 40° F. to 38° F., as 1 lb. of water cooling 1° F. gives off 1 B.Th.U. the volume of water at a drop of 2° F. required to be circulated per hour will be:—

$$\frac{800{,}000}{2} = 400{,}000 \text{ lb.}$$

approximately 40,000 gallons.

In working this system the electric power absorbed in driving pumps and compressor is more efficiently used than if electricity was used direct for heating by coil resistance.—*L. J. Overton.*

HEAT UNITS. The following are the chief units used in heat calculations.

British Thermal Unit (B.Th.U.—often B.T.U., the original contraction, which is likely to be confused with the electrical unit and therefore is not employed in this work). The quantity of heat required at normal pressure to raise one pound of water through one degree Fahrenheit. A more accurate definition, since there are 180 degree divisions in the Fahrenheit scale, is that one B.Th.U. is 1/180 the amount of heat required to raise one pound of water from 32° F. to 212° F. In order to raise 50 lb. of water through 20° Fahrenheit, therefore, 50×20, or 1,000 B.Th.U. would be required.

It is in terms of B.Th.U. that heat equivalents of other forms of energy are expressed. For instance, 1 kilowatt-hour (*see* Electricity, p. 351) equals 3,415 B.Th.U., and mechanical energy, expressed in ft. lb., is related to heat by the equation: 1 B.Th.U.=772 ft. lb. The B.Th.U. is the most widely employed of all heat units, as it is used to express the heating capacity of all apparatus—whether hot water, steam, gas, or electricity—the calorific value of fuels, latent and specific heat, heat loss, and for many other calculations.

Calorie. The unit of heat used in the metric system which corresponds to the B.Th.U. in the British system. A small calorie, or gramme-calorie (c), is the amount of heat required at normal pressure to raise one gramme of water through one degree Centigrade; or, more accurately, from 15° to 16° C. The large calorie, or kilo-calorie (C), is the amount of heat required to raise one kilogramme of water through one degree Centigrade. The large calorie is a thousand times greater than the small calorie, and is equal to 3·97 B.Th.U.; 1 B.Th.U. per sq. ft. equals 2·71 calories per sq. metre.

The mechanical equivalent of heat, or Joule's equivalent, is related to heat by the equation: 1 gramme-calorie=4·185 joules. The mechanical equivalent of heat is the amount of mechanical energy required to raise one pound of water through one degree Centigrade.

Joule. A heat unit expressed in terms of electricity and not to be confused with Joule's equivalent. It is the amount of heat generated when a current of one ampere flows for one second against a resistance of one ohm.

Therm (100,000 B.Th.U.). The therm represents the quantity of gas required to produce 100,000 B.Th.U. on combustion, and is the unit by which gas is sold to the consumer. Therm is also another name for gramme-calorie (*see* under definition of Calorie, *above*).

Degree. The unit of temperature, whose absolute value depends on whether the scale is Centigrade, Fahrenheit, or

Réamur; 4 Réamur degrees = 5 Centigrade = 9 Fahrenheit. (*See also* Centigrade; Fahrenheit.) There are 100 degrees from the melting point of ice (0°) to the boiling point of water (100°) in the Centigrade scale; 180 degrees in the Fahrenheit scale (32° melting point, 212° boiling point); and 80 degrees in the Réamur scale (0° melting point, 80° boiling point).—*E. V. Penn, M.A.*

See Heat.

HEMP. Used by the plumber for rendering watertight certain joints which require a "packing." It is usually purchased by weight in coils, twisted loosely, and can easily be unravelled, so that a packing of any size can be made. For use on cylinder or other unions which have not a ground joint, the hemp may be unravelled off the coil and twisted to form a soft twine, on to which the jointing compound may be applied with the finger and thumb. Hemp is often used to wrap round the spigot end of wrought-iron pipes after they have been threaded and the jointing compound has been applied; it is in this case used in strands rather than in the form of twine.

HIGH PRESSURE SYSTEM: Acetylene. System of welding, cutting, or brazing which depends upon the use of acetylene under high pressure. This name has come to imply the use of "dissolved acetylene," compressed into steel cylinders containing a porous mass and a solvent, acetone. The pressure is 225 lb. per sq. in. The acetylene is not, of course, used under such a high pressure, but it is employed in the blow-pipe at pressures higher than those used when the acetylene is taken from generators. During recent years, however, there have appeared on the market generators which work at high pressure; and also acetylene boosters which increase the pressure of the acetylene in the mains above that at which it is produced in the generator, but below that at which it is taken from acetylene cylinders.

See Fusion Cutting; Welding.

HOSPITALS: (1) NOTES ON SANITARY FITTINGS

By E. Thomas Swinson, F.R.San.I.,
Late Chief Inspector, Public Health Dept., London County Council

Information is here given about the special fittings used in hospitals and nursing homes, with details of typical patterns. For the plumbing, etc., the reader should refer to individual articles elsewhere in this work under such headings as Bath, Flushing Cistern; Lavatory Basin, Sink. Ventilation, heating and hot water supply to hospitals are dealt with in the second article of the present group. Layouts for Sanitary units, etc., are given in Coloured Plate facing page 536.

Hospitals are broadly classified as (*a*) general and (*b*) special hospitals, the former principally for the treatment of medical and surgical acute sick cases, and the latter for the treatment of patients for whom segregation is necessary, *e.g.* infectious diseases, tuberculosis, mental diseases, epilepsy, and orthopaedics.

In a hospital sanitary fittings of types common to other buildings are installed, but in addition many fittings of special design are essential—for the personal use or treatment of patients, for the use of the medical, nursing and other members of the administrative staff, and for kitchens, laundries, operating theatres, post-mortem rooms and mortuaries.

It is customary in a modern hospital to provide a main sanitary unit situated within the administrative section and directly accessible from the main ward and service corridor. From a staff working standpoint it is considered that this unit should not be at a greater distance than 64 ft. from any bed in the ward. If the length of the ward makes this impossible, a subsidiary sanitary section or annexe is necessary.

Main Sanitary Unit. Generally, the main sanitary unit should contain bath, lavatory basin, and water-closet accommodation, and a sink room fitted with a bed-pan sink and racks, scalding sink, slab, and mackintosh rails, a bowl or bed-pan sterilizer, and a ventilated bed-pan storage cupboard. The subsidiary section or annexe can be fitted with a bed-pan, racks and cupboard, a scalding sink, and a sink for general purposes provided with a hot and cold water supply.

Fig. 1 (Figs. 1–5 are printed in Plate *facing page* 536 (illustrates a main sanitary unit for a general hospital. Figs. 2 and 3 show by plan and section alternative layouts of sink room fittings, the distinc-

tion between the layouts being the provision in Fig. 2, (*see* Plate) of a bed-pan sink and in Fig. 3, (*see* Plate) of a special bed-pan washer.

For patients' use in the ward of a general hospital, wash or lavatory basins should be provided. Such fittings may be in the ward, partly enclosed by a glazed screen. Fittings of this type are desirable also in each isolation ward for the use of doctors and nurses, and can be fixed on each side of a partition separating two wards, that is, back-to-back, thereby permitting grouping of waste pipes and supply services (*see* Fig. 4 in Plate *f.p.* 536).

The bathing arrangements for patients in infectious disease hospitals require special consideration. The practice mostly followed is blanket bathing, but bathrooms and fixed baths are also required. For " isolation " or " separation " wards containing single beds, one bathroom is suggested for every twelve wards. In these hospitals the practice is sometimes followed of fixing lavatory basins for the patients' use in the service corridor. Where this is done, protection against frost should be assured. The sterilization of the patients' crockery and cutlery and enamelled iron ware is necessary in infectious diseases wards and hospitals, and can be carried out most effectually in steam sterilizers.

In the maternity department of a hospital a babies' bathroom is essential, with fixed baths not too close together, a slop sink, bed-pan washer, incinerator, and a steam sterilizer for bed-pans.

For a dental department sinks and lavatory basins are needed, with hot and cold water supplies, a fountain spittoon with saliva ejector, and in the " recovery " room a bubbling fountain at which patients can apply their mouths direct to the water, so obviating the use of mugs.

Where a laboratory is provided, staining sinks fitted with swan-neck taps (cold supply) and one or more sinks of " Belfast " pattern, with hot and cold water supplies, are requisite.

For out-patients' departments sufficient accommodation in the way of sanitary conveniences is incumbent.

Administrative Block. Facilities in the form of lavatory basins, sinks and sanitary conveniences are necessities in the administrative block—in which are included offices, waiting rooms, steward's stores, main kitchen with wash-up sculleries, dispensary, mess-rooms, and residential quarters for the various grades of staff. The fittings needed are similar to those provided in buildings used for other purposes, and therefore need not be described in this article with the exception of special provision for the resident medical and nursing staff. For these the conditions vary so greatly that it is difficult to lay down a standard of accommodation, but the following will serve as a guide.

Medical Staff. A lavatory basin in every bedroom and one bathroom for every four residents.

Nursing Staff (Female). Bathrooms and water-closets in a sanitary section in the ratio of not less than one to eight and not more than one to six staff—grouped on each bedroom floor in proportion to the number of bedrooms. One lavatory basin in each sanitary section. Hair shampoo facilities—one basin to 50 nurses—together with shock-proof hair-drying arrangement. Personal laundry facilities —a small room equipped with sinks, drying, ironing and airing apparatus. Lavatories and cloakrooms in close proximity to dining rooms. In each bedroom a fixed lavatory basin with hot and cold water, minimum size 18 in. by 10½ in., with a wide margin at the back of the basin at basin level for water bottle, glass, etc., with a towel rail at each side.

Nursing Home. A plan of sanitary unit for a nursing home (four floors) is given in Fig 5, (*see* Plate *f.p.* 536).

DESCRIPTION OF FITTINGS

In any description of fittings it should be borne in mind, particularly in regard to fittings in hospitals, that they are very liable to change in character and design as experience is gained in their use, and consequently little useful purpose would be served by suggesting a specification except in general terms. The simplest method of indicating the actual needs is possibly by a description of the various fittings under their respective heads.

Baths. Notes on baths suitable for hospital use are given under the heading Baths and Bathrooms (*which see*).

Lavatory Basins. Lavatory basins, whatever the position or use, should be made of white glazed fireclay or vitreous china. A brief description of basins

suitable for ward use is as follows: basins to have deep bowls and weir overflows; to be fixed 2 in. clear of wall surfaces on porcelain enamelled cast-iron cantilever brackets pinned into wall if over 3 in. in thickness; where fixed next to a wall 3 in. or less in thickness the brackets to be bolted through to back plates, the front ends to have porcelain enamelled wrought-iron or tubular legs with socket and flanges for screwing to floors. Basins to have white-metal gratings and outlets slotted for overflows; with screwed unions and lock-nuts for $1\frac{1}{4}$-in. wastes; and $\frac{1}{2}$-in. hot and cold heavy pattern press or screw-down, easy-clean pattern non-concussive white-metal valves with adjusting screw under cap, vulcanite or woodite plugs and white-metal chains.

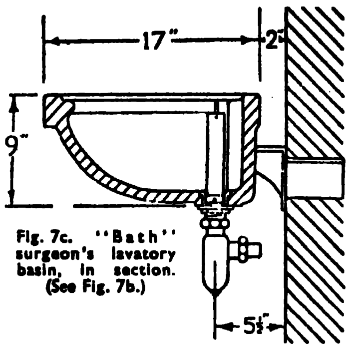
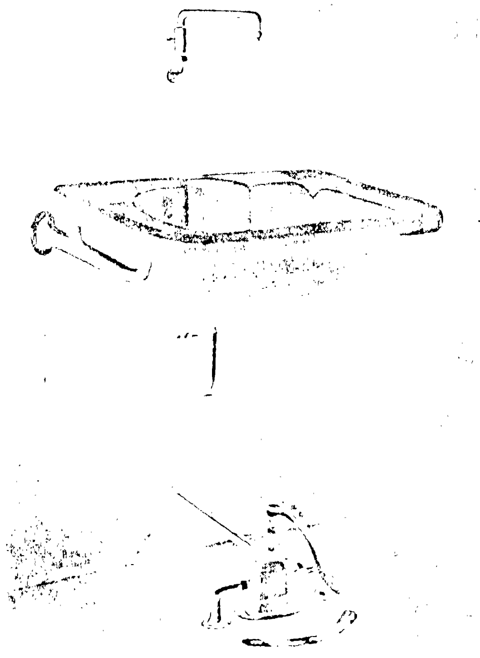


Fig. 7c. "Bath" surgeon's lavatory basin, in section. (See Fig. 7b.)

Surgeons' Lavatory Basins. For use in operating theatres and post-mortem rooms special lavatory basins are required for the use of the surgical staff. Various designs are favoured. Figs. 7a and 7b illustrate two suitable types. The second pattern is shown in section by Fig. 7c.

Lavatory Troughs. Some surgeons prefer lavatory troughs of the type shown by Fig. 8. These fittings should be of white glazed fireclay or vitreous china, of rounded interior section to prevent splashing, with a $1\frac{1}{4}$-in. waste outlet, and fixed so that the tops are 2 ft. 7 in. above the floor level, $2\frac{1}{2}$-in. clear of the wall faces; supported on porcelain enamelled cantilever brackets with studs cast on to fit into dowel holes on underside of trough. Details of fixing to be as intimated for basins for ward use, and supply valves with quick turn action and long hospital pattern levers.

Sinks. For general use, sinks of the Belfast pattern, as illustrated by Fig. 9 (p. 531), are serviceable. They should be of heavy pattern white glazed fireclay with low open-ended weir overflows, having white-metal gratings and outlets slotted for



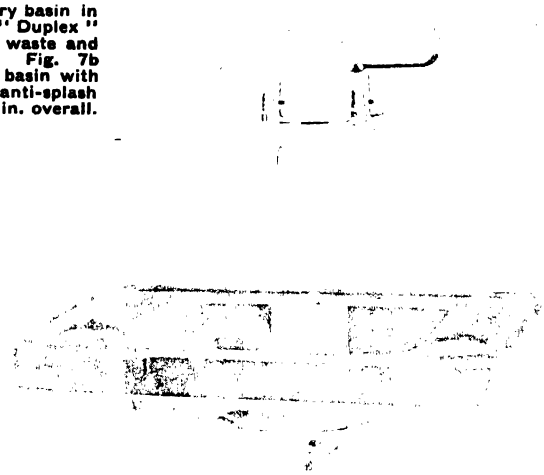
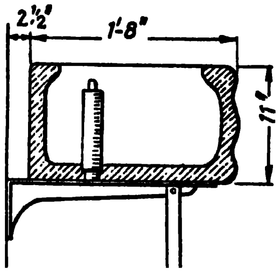
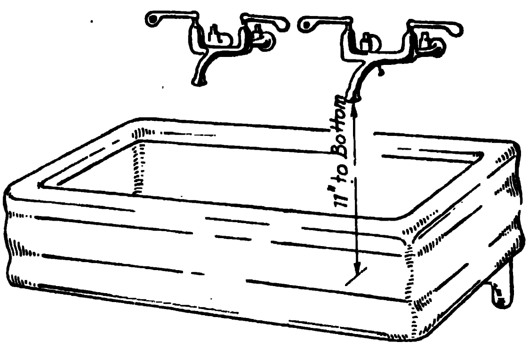


Fig. 7a (above). "Surgeon's" lavatory basin in white glazed fireclay with foot-action "Duplex" mixing valve and vulcanite standing waste and overflow. (*Dent and Hellyer, Ltd.*) Fig. 7b (right). "Bath" surgeon's lavatory basin with quick turn wrist-action supply valves, anti-splash nozzle, and c.-i. brackets; 32 by 17 in. overall. *Leeds Fireclay Co. Ltd.*

overflows, with tail unions and lock-nuts for 1½-in. wastes; vulcanite or woodite plugs with white-metal chains; ½-in. hot and cold white-metal screw-down bottle-nose valves fixed 12 in. above the top of the sink, with white-metal stays, sleeve piece and socket on back plate. The fixing should be as for lavatory troughs.

A convenient size is 24″×18″×10″,





HOSPITALS : SANITARY FITTINGS. Fig. 8. Elevation and cross-section of lavatory trough, fixed 2½ in. off wall on porcelain-enamelled c.-i. brackets; or supported on porcelain-enamelled c.-i. legs when fixed to a partition. Valves with quick turn action and long levers; 2 ft. 6 in. or 4 ft. long by 1 ft. 8 in. wide by 11 in. deep.

but the following are also found to be useful: 18″ × 15″ × 8″; 30″ × 20″ × 10″; 36″ × 24″ × 10″; and 38″ × 22″ × 10″.

Scalding Sinks. These are essential in most hospitals. A standard type is illustrated by Fig. 10, made in white glazed fireclay. The most usual sizes are 2′ 6″ × 1′ 8″ × 10″, and 3′ 6″ × 1′ 8″ × 10″ overall;

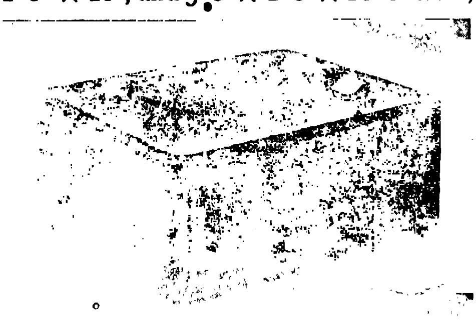


Fig. 9. "Belfast" sink in glazed fireclay with open weir overflow, white metal gratings, and outlets slotted for overflows.
Dent and Hellyer, Ltd.

with 1½″ or 2″ waste outlets. The sinks should be fixed 2″ clear of the wall faces, with the top 2′ 7″ above the floor. Supply valves (hot and cold) should be of the quick turn action with long hospital pattern levers.

Slop Sinks or Hoppers. For the reception of foul solid and liquid matters and their direct discharge into a soil pipe or drain, slop sinks or hoppers of special design are needed. Fig. 11 illustrates one of standard design fitted with a flushing rim and cistern and hot and cold draw-off valves over the sink. A combined mackintosh and slop sink is frequently used in place of separate fittings.

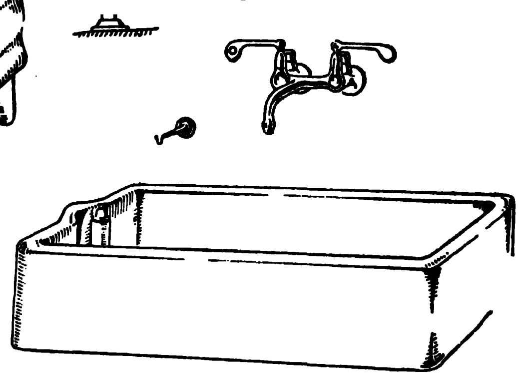


Fig. 10. Scalding sink with end recess for vulcanite standing waste; 42 in. by 20 in. by 10 in.; cantilever brackets with cast-on studs fitted into holes under sink, and built into brick wall or screwed to partition.

Bed-Pan Sinks or Sluices. For emptying and cleansing bed-pans and urine bottles a bed-pan sink is commonly installed. Fig. 12 indicates a standard type. This fitting is also often combined with a mackintosh sink.

Flushing of Sinks. Adequate flushing arrangements must be provided for the cleansing of slop sinks and bed-pan sinks, bed-pans and urine bottles. For

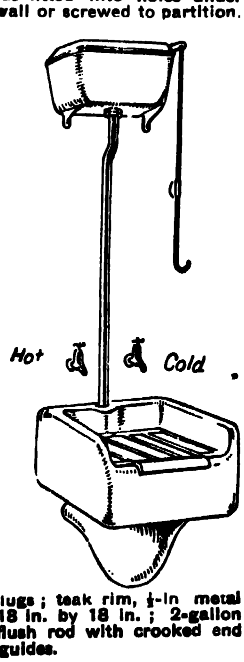
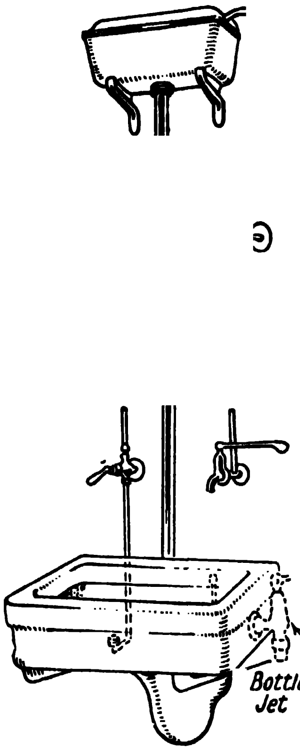


Fig. 11. Slop hopper with lugs; teak rim, ½-in metal grid, screw-down valves, 18 in. by 18 in.; 2-gallon c.-i. enamelled cistern; flush rod with crooked end and guides.



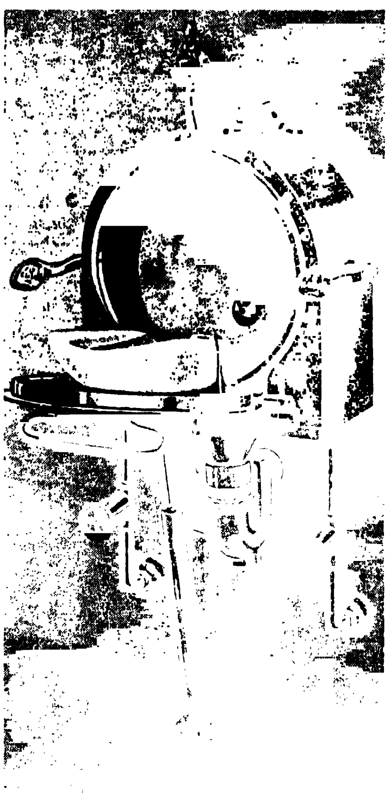
HOSPITALS SANITARY FITTINGS. Fig. 12 (left). Bed-pan sink with flushing rim, and jets, on enam. c.-i. cantilever brackets ; 26 in. by 20 in. ; 2-gallon c.-i. enamelled cistern. Fig. 13 (above). "Neosan" bed-pan and urine bottle washer built into wall, metal container, pedal-operated door, self-closing valves, vent and P trap. (*Shanks & Co., Ltd.*)

the sinks, a flushing rim is imperative and means of flushing in the form of a flushing cistern. For bed-pans and urine bottles jets are required. Flushing cisterns should have a capacity of two gallons ; they should be porcelain enamelled, of the flush flat bottom type, with valveless siphon, high or low pressure ball valve as necessary, and ¾-in. overflow. The flush pipes can be of galvanized steel tube with clips, chromium-plated connexions at head, and lead connexions to fittings. Cisterns should be fixed on porcelain enamelled iron cantilever brackets with the bottoms not less than 6 ft. 6 in. above the floor. The supply valves should be adjusted so as to fill the cisterns in not more than two minutes after discharge.

For slop sinks the draw-off valves over may be of the screw-down type except in labour rooms and operating theatres. In these cases they should be of quarter-turn lever action.

The jets for bed-pans and urine bottles should be controlled by white-metal valves with lever handles.

The water supply to jets should be derived from a storage cistern. There should be no connexion between the jets and any service pipe conveying drinking water. Slop sinks and bed-pan sinks are soil fittings, and the arrangement and construction of their waste pipes should be identical with those of soil pipes.



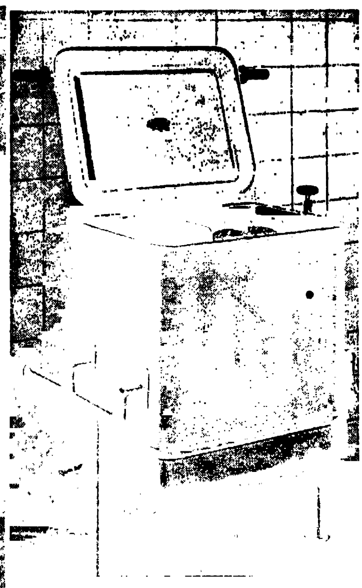
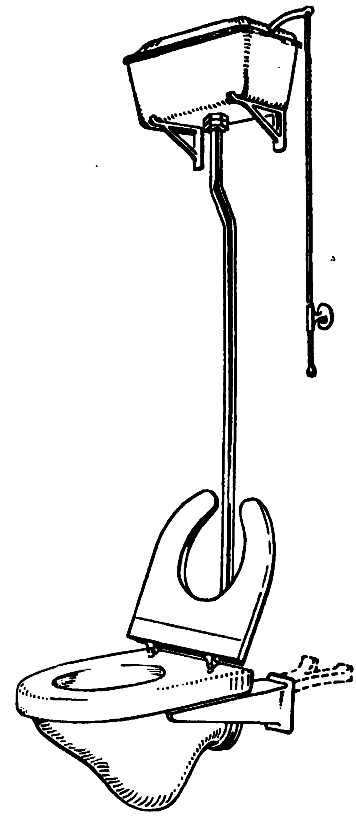


Fig. 14 (left). "Protector" bed-pan washer with porcelain enamelled c.-i. interior, counter-balanced door operated by pedal, separate stop, cold water flush, and urine bottle flush valves ; "Anti-D" trap with access plate. Fig. 15 (above). Bed-pan sterilizer of heavy gauge copper, tinned inside ; riveted and stayed steam pad ; hinged lid with underlining and insulated handles ; steam inlet and condense outlet, discharge and filling valves ; carriers for bed-pans ; heavy brackets and floor supports. (*Dent & Hellyer Ltd.*)

For drying bed-pans a heated rack is usually required and a ventilated cupboard for storing.

For urine bottles a rack is a convenience.

Bed-Pan Washers. The cleansing of bed-pans and urine bottles in bed-pan sinks is the inevitable cause of effluvium, and the emptying and cleansing of such utensils is one of the most disagreeable duties to be carried out by nurses. These circumstances can be avoided by the provision and use of automatic enclosed washers of the kind illustrated by Figs. 13 and 14. The vent pipes to these washers should discharge into a vertical 2-in. external cast-iron, coated pipe carried to a suitable position where nuisance is not likely to be caused. The waste pipe should be trapped and discharge into a soil pipe junction, and the trap should be ventilated by a 2-in. pipe arranged in the customary manner for soil fittings.



HOSPITALS: SANITARY FITTINGS. Fig. 16 (above). "Projector" enclosed wash-down closet: white fireclay closet for building into wall; teak insets, 3-gallon low-level cistern with central thumb-press lever in sloping cover; "Duro" valve fittings; ball cock (*Shanks & Co., Ltd.*). Fig. 17 (right). W.C., bracket pattern on white enamelled c.-i. brackets pinned into wall; "Paragon" rubber non-contact seat on pillar hinges; 2-gallon enamelled c.-i. cistern on cantilever brackets, 1¼ in. off wall.

The claim is made in some quarters that these washers can be used for sterilizing bed-pans after cleansing, but a better and safer course is to provide a sterilizer of approved type (Fig. 15).

Water Closets. For fixing within hospital ward blocks, water closets of the bracket or projector pattern (Figs. 16 and 17) are best—fixed clear of walls and floors. A typical fitting of the bracket pattern is illustrated in Fig. 17. It should be fixed on white porcelain enamelled cast-iron brackets pinned into walls, as indicated in the sketch. Paragon rubber non-contact seats are to be recommended, as shown on this closet. Flushing cisterns, fittings, and fixings can be as described previously (*see* page 531). Low-down pedestal fittings (Fig. 18) are satisfactory for children's use. The pattern illustrated has teak insets.

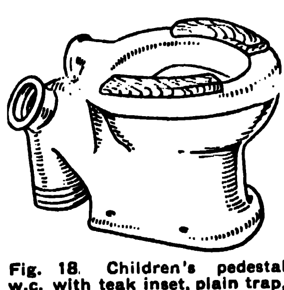


Fig. 18. Children's pedestal w.c. with teak inset, plain trap, and inspection cover; 10 in. to 14 in. high.

In the administrative block good type pedestal fittings can be fixed. Suitable patterns are included among those described and illustrated in the article on Water Closets (*which see*).

For patients' use in mental hospitals and the like an enclosed fitting offering the least opportunity for injury or misuse is imperative. Fig. 16 at the top of the page shows a fitting of this character. Being of the projector pattern it is clear of the floor, and is firmly built into the wall. Teak insets are fixed for the seat. The low-level cistern is operated by a thumb-press lever in the centre of the sloping cover.

HOSPITALS: (2) HEATING, HOT WATER SUPPLY AND VENTILATION

By L. C. C. Rayner, A.I.E.C.

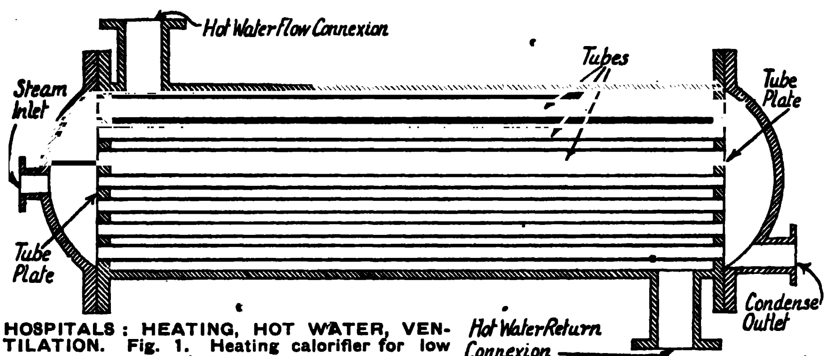
Sanitary fittings, etc. of hospitals having been dealt with in the preceding article, the present contribution discusses the requirements in the way of Heating, Hot Water Supply and Ventilation. For general practice in these departments the reader should refer to the articles elsewhere under appropriate headings.

The first essential of any hospital equipment is that it shall be completely reliable, and this applies especially to the mechanical equipment to be discussed in this article. Every item should be of good quality, and particularly such things as valves which are a source of continuous maintenance to avoid breakdown.

Boiler Installation. Starting at the boiler house, most hospitals require a supply of steam for sterilizers (which will be distributed throughout the hospital), for the kitchen, and, in a big hospital, for the laundry. The usual practice, therefore, is to use steam boilers only, warming by calorifiers (*which see*) any hot water required. The number of boiler units required will depend on the load and its variation throughout the year. Most certainly at least two should be used, with sufficient capacity to have a margin over the maximum likely demand for steam. To arrive at this demand is not simply a question of adding up the various loads. The maximum consumption of steam by the sterilizers will not coincide with the maximum consumption of hot water for baths, but may with the maximum kitchen demand. Such factors must be considered in determining the proper boiler power.

The most usual boiler is the "Economic," also called the horizontal return-tube, and occasionally the dryback. The last term really embraces several other types of boiler, and should not be used. The most modern type of Economic boiler is known as the high velocity type. It has small fire tubes and uses an induced draught fan to draw the flue gases through them at high velocity. It has a high efficiency but requires more frequent and skilled attention than the normal type.

The necessary adjuncts to the steam boilers will be required, such as boiler feed pumps, condense tanks, make-up tanks, etc. All that need be said here is that every opportunity should be taken to avoid waste. The exhaust steam from the pumps should be used in calorifiers to supply hot water. The boilers will usually run at 60 to 100 lb. per sq. in. pressure, to enable the use of economical pumps and to reduce waste in supplying steam to the farthest parts of the hospital.



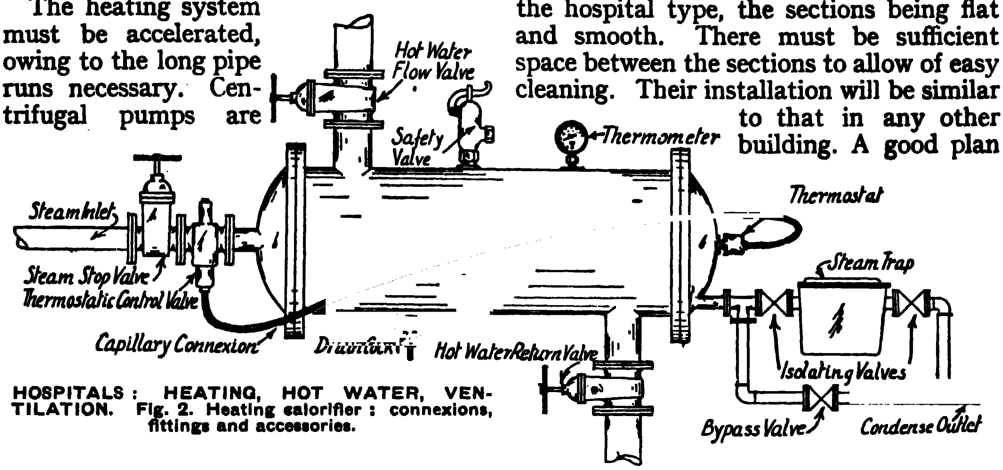
HOSPITALS: HEATING, HOT WATER, VENTILATION. Fig. 1. Heating calorifier for low pressure hot water system.

Heating System. The heating will usually be effected by low pressure hot water. Calorifiers of the type shown in Fig. 1 should be used. It will be seen that the waterway is inaccessible for cleaning. This will be quite satisfactory, since the same water will be circulated through it continuously. Locate the calorifiers in the central boiler house and not in each ward block. Thus leaky joints and traps will not go undetected, and unnecessary duplication of pipes is avoided.

Maintenance costs will be reduced also because the number of units will be smaller and they will be accessible. The calorifiers should have bucket-type steam traps with isolating and bypass valves, thermostatic temperature regulating valve, steam stop valve, flow and return valves, thermometer, safety valve and drain cock. These are shown in Fig. 2. The calorifiers are usually carried on cradles.

They should be in duplicate, or, if the load is large enough, in triplicate, so that one is available always as a standby.

The heating system must be accelerated, owing to the long pipe runs necessary. Centrifugal pumps are employed almost exclusively for this purpose. They are usually driven by turbines using steam from the boilers, the exhaust steam being employed in the hot water supply calorifiers. Here again a standby is necessary, and for this an electrically driven accelerator is often employed so that when steam is not available the accelerator may still be used.



HOSPITALS : HEATING, HOT WATER, VENTILATION. Fig. 2. Heating calorifier : connexions, fittings and accessories.

For actual delivery of heat to the rooms, radiant heaters of the internal panel type or external "Rayrad" type are often employed (*see* Fig 1, p. 848). They have the advantages of presenting no recesses for the lodgment of dust, and the surface being flat is very easily kept clean. For the heating of open sun balconies, radiant heaters on the ceiling are undoubtedly best. *See* Radiant Heating.

One disadvantage of radiant heating is the initial cost, and for this reason radiators are more usual. They should be of the hospital type, the sections being flat and smooth. There must be sufficient space between the sections to allow of easy cleaning. Their installation will be similar to that in any other building. A good plan for the wards is to arrange radiators between every other bed, as shown in Fig. 3. In this way even distribution of heat will be obtained and space will be available for bedside cabinets, etc. The radiators should be without feet, carried on cantilever brackets at least 4 in. clear of the floor. There should be a 2 in. space between the back of the radiators and the wall. In operating theatres the radiators are often joined to the pipes with swinging connexions (supplied by the manufacturers) to swing out the radiator for cleaning. In the operating theatre, too, some radiators are often supplied from the hot water supply to provide heat when the heating system is out of use in the summer.

Wards are usually designed for an internal temperature of 65° or 70° F.,

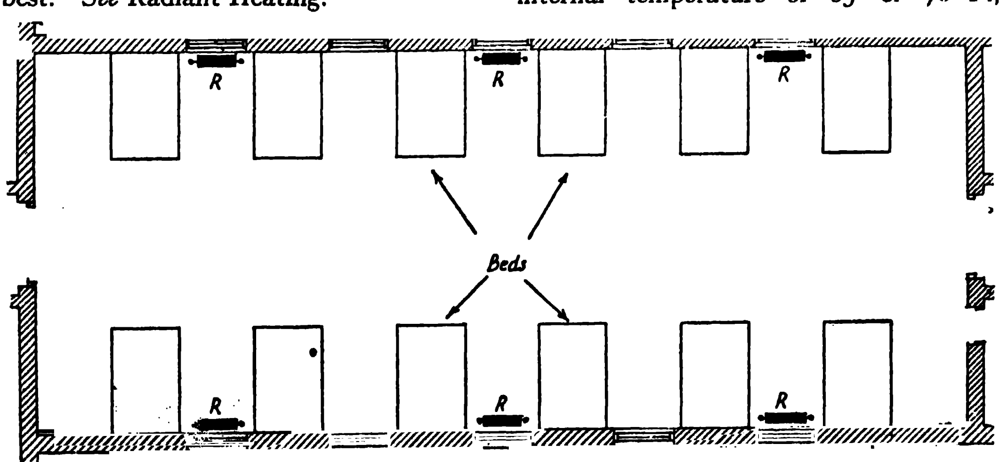
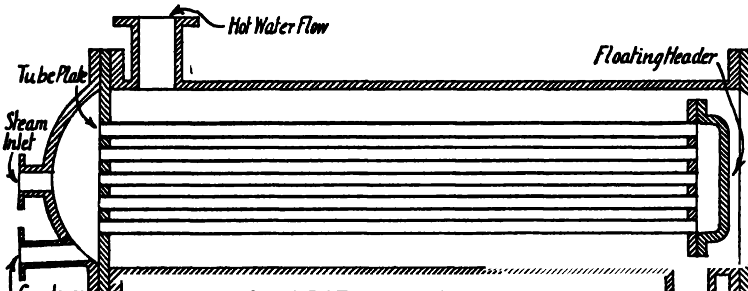


Fig. 3. Radiators in ward placed between every other bed, for even distribution of heat and to allow alternate spaces for bedside cabinets.

with not less than two air changes per hour (and more if there is cross ventilation). The operating theatre will require a temperature of 75° to 80° F.



HOSPITALS: HEATING, HOT WATER, VENTILATION. Fig. 4. Hot water supply non-storage calorifier, for use in conjunction with storage cylinder.

Hot Water Supply. The supply for a hospital is usually provided by storage calorifiers (dealt with under the heading Calorifier). A more economical and flexible arrangement is to use storage cylinders coupled to non-storage calorifiers, as Fig. 4. These are like that in Fig. 1, but the tube battery is removable for cleaning. Similar accessories will be required to those shown in Fig. 2. By employing these calorifiers one may be arranged to act as standby to both heating and hot water supply, dispensing with a separate unit for the heating. The arrangement will then be similar to Fig. 5. Occasionally separate calorifiers are installed for live and exhaust steam when the quantity of the latter is subject to wide fluctuations. This might be the case when exhaust steam from a laundry was used.

The hot water supply circulation will also need to be accelerated owing to the long runs involved. A standby unit is again required. To save expense one accelerator may be used as a standby to both heating and hot water supply systems, provided the duties required are approximately the same.

In addition to the normal supply to baths, basins, sinks and towel rails, it is probable that hot water will be required for bed-pan and urine bottle racks and mackintosh sinks. The hot water circulates through the racks to dry the vessels on them. These fittings will be found in the sanitary annexes.

In arriving at the probable demand for hot water allow 10 gal. per person for the peak hour, or 50 gal. per day. In computing the number of people, include both patients and staff. As a check, count the number of fittings and allow 9 gal. per bath, 5 per basin, 12 per sink and 60 per shower for the peak hour. All these figures assume hot water at 150° F., and should be varied in proportion for other temperatures. Keep all exposed pipes well off floors and walls for cleaning.

Ventilation. Usually the only parts of a hospital requiring mechanical ventilation are the operating theatre and occasionally the sterilizing rooms and X-ray rooms. The wards will have natural cross ventilation. If this is not possible, a balanced supply and extract system should be used. It is essential that the entering air be filtered so as to be dust and germ free; draughts and noise must also be avoided. If ventilation is required in the X-ray rooms the only special precaution that may be necessary is the use of light traps. Sterilizing rooms occasionally need a hood over the sterilizers connected to a

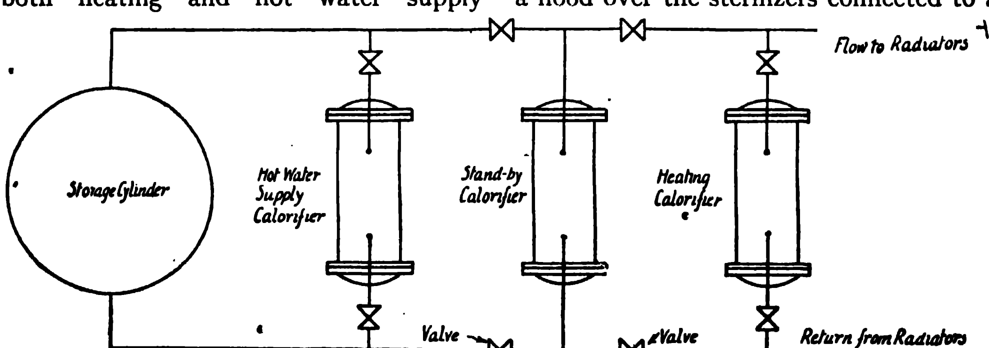


Fig. 5. Inter-connexions to enable one calorifier to act as standby to both heating and hot water supplies.

propeller fan to remove vapour. In all cases every part of the plant and ducts must be accessible for cleaning.

Steam Supply. Low pressure steam will be needed in the ward kitchens and wherever there are sterilizers. If long runs are involved it is often more economical to take high-pressure steam to a point convenient to the wards and install a reducing valve to obtain the requisite low pressure.

In a very small hospital, steam may not be used, the sterilizers, etc., being heated by electricity. In such cases the design will follow normal practice, the special points discussed above being included.

HOTEL AND CATERING TRADES: (1) SANITARY FITTINGS

By E. Thomas Swinson, F.R.San.I.

Late Chief Inspector, Public Health Department, L.C.C.

Here are set out the requirements of hotels, restaurants and any similar buildings. The sections are: A, Residential Suites; B, Service and Staff requirements; C, Fittings. Layout plans are given in the coloured Plate facing page 544. The second article of this Group covers Hot Water and Heating requirements.

See Bath; Bidet; Lavatory Basin; Sink; Water Closet.

(Note. Figs. 1 to 5 are given in Plate facing pages 544 and 545).

The provision to be made in the form of sanitary, ablutionary and waste water fittings can be subdivided into requirements for:

(a) Residential suites and sleeping apartments; (b) general and public use; and (c) service and staff.

In the planning of new residential hotels, suites or bedrooms complete with ablutionary and other conveniences are now regarded as essential; and many existing hotels and boarding-houses are being modernized so as to provide, as nearly as may be possible (having regard to the structural conditions), similar provision for improving the amenities of the building and lessening the labour required in attendance.

A. RESIDENTIAL SUITES

Bedroom Equipment. The least accommodation expected is a lavatory basin in every bedroom, complete with hot and cold water supplies. The arrangements made depend upon the layout of the apartments, but in the interests of economy the grouping of the fitments is desirable. With apartments adjoining, the simplest method is to fix lavatory basins back to back (Fig. 1A) or as near the partition wall as practicable (Fig. 1B), the fittings being alined vertically so that a single main waste pipe and services serve the fittings on each floor.

With good-class buildings the avoidance of unsightly pipework on the façade is often desired, and for this reason, and also from the standpoint of accessibility, preference is given to its construction within the building. For the sake of appearance within the building, as much pipework as possible should be out of sight in chases or recesses, with flush removable panels affording ready access (*see* illustrations *under* Building Construction *and* One-Pipe System), a method practicable in new buildings but not always applicable to existing buildings. In the latter the means of enclosure are usually restricted to casings.

Bathrooms. Where more extensive provision than a lavatory basin is required, this may take the form of a bathroom approached direct from the bedroom and fitted with bath, lavatory basin, water-closet and/or a bidet. Here, again, grouping of the bathrooms in adjoining suites is desirable for an economical arrangement of the pipework. Fig. 2 shows two fitted-up bathrooms in adjoining suites (repeated on other floors), the bathrooms being lighted and ventilated by windows in the external wall. With this arrangement the waste pipes of the ablutionary fittings can be kept separate from the soil pipe receiving discharges from the water closets, or all the waste matters may discharge by a single pipe, *i.e.* the "one-pipe" system, as in Fig. 2.

A typical mode of planning for a large hotel is that illustrated by Fig. 4 in the Bath Plate *f.p.* 93.

The bathrooms are constructed in an internal position, thus reserving the external walls of the building for habitable rooms; they are ventilated by mechanical means, and a large central duct is formed in which all waste, ventilating and service

pipes are installed. Such grouping and duct provision eminently favours the economical application of the one-pipe system to the soil and ablutionary fittings.

Sanitary Unit. In many hotels and boarding-houses the provision made in suites or bedrooms is limited to lavatory basins. In such case a sanitary unit (comprising fittings not elsewhere provided) is necessary, so placed as to be accessible to the occupants of the bedrooms.

The number of sanitary units on each floor and the number of fittings installed depend on the number of rooms to be served. The provision of one fitting of each type for every 8 to 10 bedrooms may be regarded as reasonable accommodation, but in determining the number regard must be had to the class of hotel or boarding-house. If of the commercial class there is often considerable demand for access to the conveniences within a limited time. Fig. 3 shows a plan of a sanitary unit for general use on a floor basis of twenty bedrooms.

One or more service sanitary units are needed on every floor, and these should contain a sink with hot and cold water supplies over and a slop sink. A water closet for staff use is also desirable.

General and Public Use. In addition to the specific needs as suggested for the bedroom floors, conveniences for general use in positions easily reached from dining, billiards and smoking-rooms, lounge, etc., are essential. The extent of the accommodation depends upon the amount of use likely. If restricted to residents the provision need not necessarily be extensive; but if public dining-rooms, dancing-rooms, or rooms used for public functions are within the building, the conveniences should be based upon the maximum number of persons who can be accommodated at any one time.

No golden rule can be laid down, but as buildings used for the purposes indicated are commonly licensed for music and dancing, the sanitary accommodation should approximate to that required for licensed places, of which the following is an example:

Males:
- One water closet for the first 200;
- Two water closets for 200–500;
- Three water closets for 500–1,000; and
- One additional water closet for every 500 or part thereof over 1,000.
- One urinal stall for every 100.

Females:
- One water closet for the first 100;
- Two water closets for 100–250;
- Three water closets for 250–500; and
- One additional water closet for every 400 or part thereof over 500.

The standard here set out is not a high one, and where the use of any portion of the building is subject to rush hours or periods, it may be found inadequate. The factory standard (*see under* Factories) more nearly meets the need where public dances and other functions are catered for.

Restaurants and Licensed Premises. In these (as distinct from hotels) suitable accommodation should be provided. The necessity for such is now recognized by many licensees, and is usually insisted upon by the licensing authority. The number and type of conveniences depend upon the number of persons accommodated and the character of the business carried on.

Sanitary conveniences should not be entered directly from restaurants, public rooms, or places in which food or drink for man is prepared, stored or sold. The entrance should be through a ventilated approach lobby. A customary form of planning where the public is admitted is through a cloakroom as shown in Fig. 4, which illustrates conveniences for males and females each approached through a cloakroom, the urinal apartment being aerially disconnected from the cloakroom by an apartment fitted with lavatory basins.

Where hairdressing saloons are provided, lavatory basins are needed fixed with sufficient space between (not less than 8 ft. centres) to allow room for use.

B. SERVICE AND STAFF REQUIREMENTS

The service requirements (*i.e.* kitchens, sculleries, and serveries) in a large hotel or catering establishment comprise ordinary type sinks with hot and cold water supplies, vegetable sinks and troughs, sinks for washing up—including suitable fittings for cooking utensils, tableware, cutlery and plate, and, on occasion, machines for washing dishes, etc.; also boiling and steaming pans for hams, vegetables, soups, milk, boiled meats; steamers for fish, potatoes, etc.; and steam kettles of the counter type for tea and coffee. Fig. 5 (*see* Plate *f. p.* 545)

illustrates a layout of kitchen, scullery, vegetable preparation room, pantry, etc.

Wall and Floor Finishings. Finishings for bathrooms are described under Baths and Bathrooms, and this description applies to all apartments housing sanitary fittings. A satisfactory finish for the walls and floors of kitchens and sculleries is a dado 8 ft. in height of glazed tiles or terrazzo, with the wall surfaces above painted. For floors a finish of terrazzo or quarry tiles is suggested as suitable.

Drainage. The removal of waste water and floor drainage from kitchens and sculleries needs special attention. The waste water from boiling and steaming pans, plate washers, etc., should be discharged into open glazed-ware channels leading to trapped gullies outside the building. Drain inlets within a place where food is prepared or stored are not permissible. Waste pipes of sinks should be trapped immediately under the fittings, and discharge (preferably by side or back inlets) into trapped gullies situated in an external position.

Fixing Fittings. All sinks and other fittings should be fixed 6 in. clear of the walls, and pipes 2 in. clear of the walls—measured from the asbestos or other non-conducting covering material. This mode of fixing should be regarded as an essential precaution to lessen the opportunities for infestation by cockroaches, steam flies and other insects, and to allow for cleaning and the maintenance of the wall surfaces.

Disposal of Greasy Water. A matter of some difficulty in hotel and restaurant kitchens is the disposal of the waste water containing much grease. In small establishments the sink and other waste pipes can discharge into flush-out grease traps (*see under* Grease Trap) fitted with automatic flushing cisterns (*see* Flushing Cistern), and from thence to drain and sewer.

Where the quantity of greasy water cannot be thus disposed of, grease-retaining traps can be used, arranging for periodic removal of the solidified grease. For large establishments where a considerable volume of hot water is used, making it impracticable to solidify the grease in a retaining trap, receiving tanks of considerable size are needed, with frequent removal of the greasy liquid contents into skips or other receptacles, and removal from the premises for disposal elsewhere.

Staff. For resident staff one or more sanitary units should be provided in suitable positions on the bedroom floors, with bath, lavatory basin and water closet fittings for general use. A lavatory basin in every bedroom is an appreciable convenience. The type and number suggested for nursing staff in hospitals (*see* Hospitals) may be accepted as suitable.

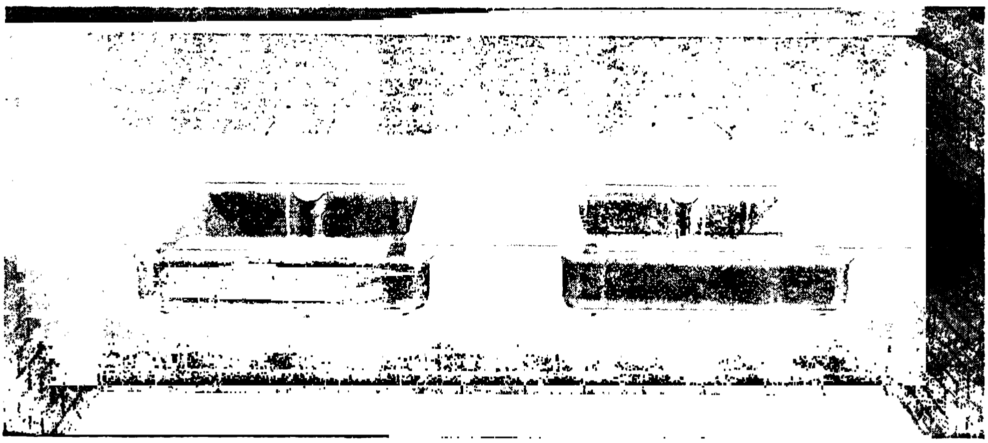
For kitchen and other staff groups, washing facilities and water closets (with urinals for males) are needed in positions readily accessible from the place of working. In the main kitchen the provision of a hand-washing trough with spray jets can be recommended.

C. SANITARY FITTINGS

Lavatory Basins, Baths and Bidets. Lavatory basins for fixing in, or in connexion with, bedrooms, or for general use in hotels, resemble those for other buildings; and the same may be said of baths. Selection rests largely upon the class of building and persons for whom the accommodation is provided—cost often being the deciding factor.

Bidets have of late years come much to the fore—particularly for installation in hotels. Properly used they are ablutionary fittings, and the waste pipes can therefore be treated identically with the waste pipes from baths and lavatory basins (but for this point the by-laws and regulations of various authorities differ; *see* Bidet). The water supply is in the form of an ascending spray and it is essential that care should be taken to avoid any backflow from the fitting into the water supply services, with the possibility of polluting water intended for drinking purposes. The safest plan is to supply the fitting from a storage cistern used only for flushing water closets, urinals, and other soil fittings.

Water Closets. Siphonic and washdown water closets are in every respect satisfactory. For use by residents or customers, seats of bakelite, or hardwood polished or finished with a hard enamel, should be fitted. For general use seats with cut-away fronts are desirable; for males, particularly where urinals are not available, the self-lifting pattern possesses advantages. Hardwood rims or insets are to be preferred to seats in the case of w.c.'s for the male staff.



HOTEL : SANITARY FITTINGS. Fig. 6. Two "Belfast" sinks combined with teakwood drainers for housemaids' sink-room : sinks of white glazed "Imperial" porcelain with weir overflow and waste in centre at back; wall-face sheath-body taps (left), and swivel mixing valves (right)) ; optional teak pads on sinks.
Leeds Fireclay Co., Ltd.

Urinals. Circular-backed stalls of glazed ware are the best, with an automatic flushing cistern capable of supplying one gallon of water to each connected stall ; the frequency of the flush is determined by what is necessary to ensure maintenance of stalls in a clean state.

Sinks. For housemaids' sink-rooms the ordinary deep wash-up sinks, fitted with draining boards or slabs with draw-off taps over are satisfactory ; and slop sinks of the kind shown by Fig. 6. The compartments in which the last named are fixed should conform to the requirements governing water closets, and the waste pipes of the slop sinks connected to soil pipes or constructed in the same manner.

For kitchen use, glazed ware sinks should be fixed in the main kitchen and similar sinks, together with sinks of special type, in the pantry. In the vegetable preparation room and pots and pans cleansing rooms, galvanized iron sinks are needed 3 to 5 ft. in length by not less than 1 ft. 6 in. in width, and not more than 1 ft. 9 in. in depth, fixed with the tops 2 ft. 9 in. above the floor.

For Figs. 1–5 see Plate facing pp. 544 and 545.

HOTEL AND CATERING TRADES: (2) HEATING, HOT WATER SUPPLY AND VENTILATION

By L. C. C. Rayner, A.I.E.C.

The general principles and main applications of Heating, Hot Water Supply and Ventilation are treated elsewhere in this work under their own headings. Here Mr. Rayner discusses the special requirements of hotels and restaurants. The sections are: A, Heating arrangements; B, Hot water supply ; C, Ventilation.

The heating of an hotel or similar building will not differ in its method of design from that of any other building. The application of the heating installation, however, may involve several somewhat unusual requirements. As an instance, parts of an hotel may be used only once each week and arrangements must be made to allow for this.

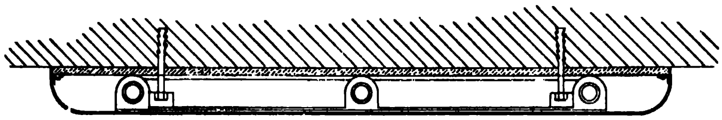
Cooking Requirements. A first matter for decision is how much, if any, cooking will be done on the premises and what method will be employed. If the cooking is considerable it is probable steam will be required. This being the case, it may be the wisest course to use steam boilers only, employing low pressure steam or hot water heated by calorifiers for the heating installation. In a large hotel this will probably be the most economical method. The design of an installation including large high pressure steam boilers is a matter for a specialist and will not be discussed further. In a smaller building large steam boilers have some disadvantages, particularly in the skilled attention they require. Here the cooking load may be comparatively small and very variable, and the more usual practice is to employ low pressure hot water heating

boilers with a small vertical steam boiler for the cooking.

A. HEATING ARRANGEMENTS

Having determined that cooking may be dealt with separately, the type of heating should be considered. In many cases (particularly in restaurants without living accommodation) central heating may not be warranted, and local heating by gas or electricity may be more economical. Or, owing to the restaurant occupying but one floor, it may be impossible to install central heating without the undesirable showing of pipes unless large sums are spent on concealing them.

Assuming that central heating is to be adopted, probably the first difficulty will be the position of radiators. In dining-



HOTEL : HEATING, HOT WATER, VENTILATION. Fig. 1. Panel heater fixed to ceiling as most convenient position and for even distribution of heat.

rooms wall space will be occupied by tables; and, in such places as bars, settees or chairs and tables will be ranged round the walls. Even if space can be found for radiators, they will often lead to uncomfortable conditions since the room occupants will in some cases be too near them and in other cases too far away. To obviate these troubles such rooms may be warmed by panels like "Rayrads" fixed on the ceilings.

Panel Warming. These panels may be of the flush type level with the plaster, in which case a beading or moulding should be fixed to cover the joints. It is essential to fix fibre insulating board ½ in. thick behind the panels, so as to prevent transmission of heat to the rooms above. The pipe connexions will need to be run in the floor over the panels. This point should be studied before designing the scheme, because a wood joist floor may present difficulties. Risers or drop pipes serving the panels should be positioned so that the connexions may run between the joists. If some joists have to be crossed, endeavour to ensure that this occurs as near supporting walls as possible where cutting the joists will have the smallest possible weakening effect. If the floor is of concrete, chases will be required for the connexions. When the building is a new one, a chase plan should be prepared to avoid unnecessary cutting away. Adequate venting is a vital factor in a satisfactory installation. Air cocks are not usually satisfactory with panels on the ceiling, since they must be fixed either on the ceiling (where they are difficult of access) or in the room above (where they may be forgotten or where access may be inconvenient). A much better plan is to fix the connexions so that they rise continuously from panels to risers. The risers may then be extended vertically to form permanent vents. To assist in this, connexions should be as short as possible; otherwise it will probably be impossible to obtain sufficient rise, owing to lack of depth in the floor. The connexions should be insulated, particularly if the floor is of wood. A good material is asbestos felt.

The calculation of panels will be similar to that of any other heating installation, and the makers will give figures for heat emission. To ensure equable warming the distribution of panels should be as even as possible. A good arrangement is to divide the room into squares having sides of not more than about 15 ft., fixing one panel in the middle of each. Panels should also be fixed in the neighbourhood of windows to prevent down-draught. If electric light fittings interfere with suitable placing of panels, those having sheet steel faces may be adopted, with holes drilled to take the fittings and conduit.

Radiators. Where panels are not desired, radiators concealed in recesses under windows have advantages. (The arrangement is shown in Fig. 2.) The recesses should have fronts, to prevent overheating of people near them. A grille is provided at the bottom for air to flow in, and a grille at the top for air to flow out. This latter grille ensures an upward

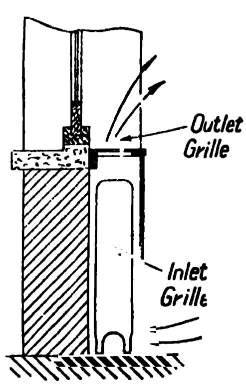


Fig. 2. Radiator concealed in recess under window: inlet grille at bottom and outlet grille at top; this arrangement ensures upward current of warmed air.

motion of the air currents and so affords good distribution. The radiator may be of the standard type or one of the finned type specially made for concealed use.

When the room is of considerable size it will be necessary to fix radiators in the interior. These may be on columns, and again are preferably concealed in a similar manner to Fig. 2. Every endeavour should be used in the type of room being discussed to make certain that the heat is evenly distributed and that no local overheating occurs.

In bars of public-houses a warm foot rail is often provided. This may be of polished steel tube, and particular care must be taken with the supports. In public-houses and hotels, wine and beer cellars have to be considered. Hot pipes must always be kept out of the former. In regard to beer cellars, brewers' requirements differ: if warmth is required it is best provided by a pipe coil fixed near the ceiling and controlled by valves. It will probably be impossible to avoid running mains through the beer cellars, but they should be very thoroughly insulated. Warmth may then be obtained or not, as required.

Bedroom Warming. Other rooms such as bedrooms, lounges, etc., in hotels and similar buildings will be treated in the normal way for heating. If the building is large enough it is worth while arranging a separate circuit for bedrooms, so that they may be controlled apart from the remainder of the building. If the staff bedrooms are on the top floor it is often an advantage to install the heating as a drop system. The flow main can then be run through the staff bedrooms and will usually heat them quite adequately. A temperature of 55° F. is usual in guests' bedrooms and 60° F. in living-rooms, lounges, dining-rooms, etc.

Electric Radiators. When it is not desired to employ central heating, electric or gas radiators may be used. Electric radiators have the big advantage of lack of fumes to dispose of. They may be plugged in at any power point and are easily controlled. Thermostatic switches may be used if desired to maintain a constant room temperature. The normal electric radiator consists of an ordinary radiator partially filled with water and with an immersion heater screwed into the bottom hub. They are made in various ratings, the most usual being 1,000 watts, 1,500 watts and 2,000 watts. The corresponding heat emissions in B.Th.U. per hour may be obtained by multiplying by 3·415. The three ratings mentioned would thus emit 3,415, 5,122 and 6,830 B.Th.U. per hour respectively. These correspond to hot water radiators having heating surfaces of 22, 33 and 44 sq. ft. Electrically heated panel radiators and tubes may also be obtained for use where ordinary radiators are unsuitable. *See* Heating: (4).

Gas Radiators. Where electricity is not available or is too costly, gas radiators may be used. They should be calculated in the same way as ordinary radiators. When the flue gases discharge into the room, no heat is wasted, but there is a practical limit to the size (or gas rate) of such a flueless heater. Each foot of gas consumed gives off 450–500 B.Th.U. per hour, and is equivalent to about 3 sq. ft. of hot water radiation. *See* Heating: (5). When determining the positions for gas or electric radiators the same general principles should be followed as for hot water radiators.

B. HOT WATER SUPPLY

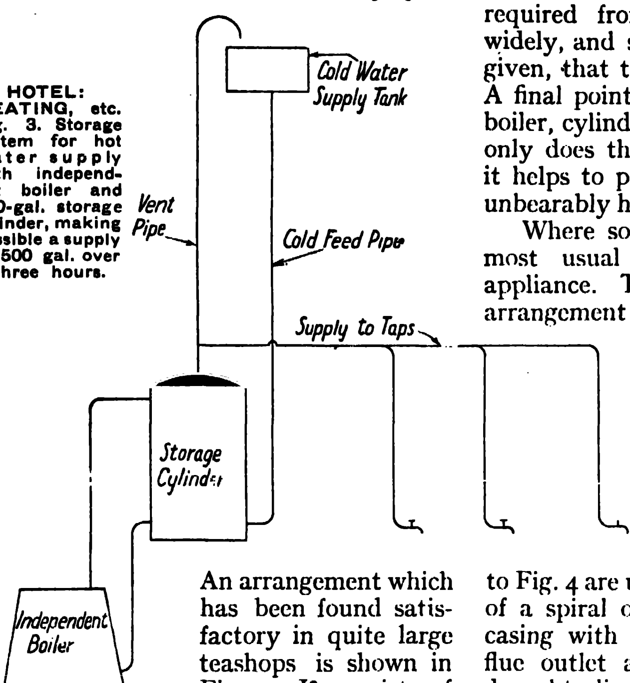
An adequate hot water supply is of prime importance in buildings where cooking is carried out. Two definite methods of arranging for the hot water supply must be distinguished—the instantaneous and the storage methods. (*See* Hot Water Supply: (4); *also* Thermal Storage System.) In the first, water is heated as it is required—which means that the appliance must be capable of heating water at the maximum rate at which it will be needed. It also means that at periods when no water is wanted the apparatus must be shut off. This system therefore lends itself only to use with heating methods that can be quickly and easily controlled.

The storage method of hot water supply involves heating water at a more or less constant rate and storing it in a vessel from which it may be drawn as required.

Most hot water supply installations are subject to large variations in demand, but this is particularly the case in buildings of the type under discussion. Very often, therefore, both methods are adopted, especially in larger buildings. As an instance, steam pipes are often fitted to

washing-up sinks. Hot or cold water is run into the sinks, and the steam jets turned on if necessary to raise the water temperature to the desired degree.

Storage Heaters. Where it is possible to use storage installations they are usually more economical. This is definitely the case if solid fuel is employed.



HOTEL: HEATING, etc. Fig. 3. Storage system for hot water supply with independent boiler and 200-gal. storage cylinder, making possible a supply of 500 gal. over three hours.

An arrangement which has been found satisfactory in quite large teashops is shown in Fig. 3. It consists of a round cast-iron hot water supply boiler coupled to a galvanized steel storage cylinder. The boiler is capable of raising the temperature of about 130 gal. of water 100° F. per hour, and the capacity of the cylinder is 200 gal. With this combination it is possible to obtain 500 gal. of really hot water over a period of three hours, assuming that the cylinder is full of hot water at the beginning of the three hours.

For such an installation to be satisfactory a few points require attention. First, a reasonable flue is necessary, since when the full boiler output is required the draught must be good. If such a flue is not available, then a gas or electric heater is to be preferred. Secondly, if the cold water supply tank is on the same floor as the boiler and cylinder, the pipes should be adequate in size. Each sink connexion should be ¾ in. Making allowance for the fact that not all the taps are likely to be in use at once, the main pipes may be of the following sizes: up to 3 taps, 1 in.; up to 7 taps, 1¼ in.; up to 13 taps, 1½ in.; up to 30 taps, 2 in. The cold feed pipe must never be less in diameter than the main pipe going to the fittings.

The boiler should be fitted with an automatic damper regulator. The output required from the boiler fluctuates so widely, and so little attention is usually given, that this fitting is very important. A final point is the efficient insulation of boiler, cylinder and circulating pipes. Not only does this prevent fuel wastage, but it helps to prevent the kitchen becoming unbearably hot—always a difficult matter.

Where solid fuel cannot be used, the most usual alternative is a gas-fired appliance. This may consist of a similar arrangement to Fig. 3, but employing a gas boiler. The requisite capacity of the boiler and cylinder may be calculated from data given below. (For the installation of the boiler, etc., *see under* Boiler: (2) and (3).) For smaller buildings self-contained boiler-cylinder units similar to Fig. 4 are used. The heater is composed of a spiral of copper tube enclosed in a casing with the gas jets below it. The flue outlet at the top is fitted with a draught diverter. The water circulates through the coil from and to the cylinder, which has a capacity of about 20 to 30 gal. The gas consumption being fairly low, the flue pipe is often omitted. If the kitchen tends to be hot, then a

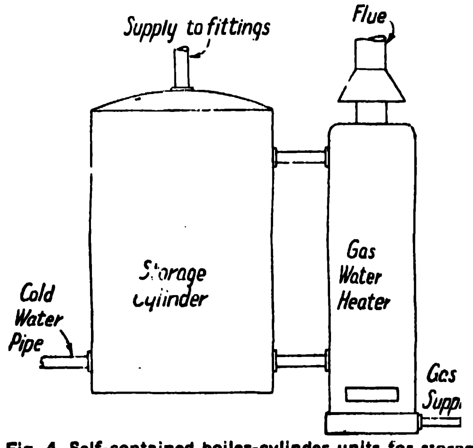
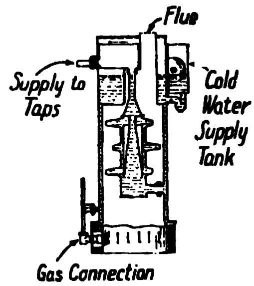


Fig. 4. Self-contained boiler-cylinder units for storage system of hot water supply, useful where smaller amounts are required than provided by system of Fig. 3; thermostatically controlled, and requiring same piping as shown above.

flue pipe should be fitted and the apparatus lagged. The heater is controlled by a thermostat, a fitting which should be included on every gas water heating appliance. The piping in connexion with Fig. 4 will be the same as in Fig. 3.



HOTEL: HEATING, HOT WATER, VENTILATION. Fig. 5. Automatic gas water heater, instantaneous type, requiring no separate cold water supply tank or flue connexion.

A still simpler method of supplying hot water is that shown in Fig. 5. This requires no separate cold water supply tank or flue connexion. It may stand anywhere after being coupled to gas and water mains, and is ready for use. It is of the instantaneous type, heating water at any rate up to its maximum as it is required. A wide range of output ratings is available. The interior is similar to a geyser.

The cold water connexion is made to the small side tank, which is fitted with a ball valve to maintain the proper water level. The supply to the taps is taken from the union on the opposite side of the heater. These water heaters are fitted with thermostats to maintain any desired temperature. Similar fittings are used to supply boiling water for tea and coffee.

Electric Water Heaters. Electricity is not often used for hot water supply in restaurants or hotels. If it is to be adopted, immersion heaters in a storage cylinder may be the best method. These are dealt with fully under the heading Immersion Heaters. The cylinder should have a storage capacity equal to the maximum two hours' demand, and the heaters should be capable of heating up the water in the cylinder in about four hours. Thermostatic control is necessary.

Calculating Hot Water Needed. The best method of determining the quantity of hot water that will be used for kitchens is from the meal capacity. It may be taken that for each meal served the hot water consumption will amount to from ½ to 1 gal. for the maximum hour and from 1½ to 3 gal. per day. The smaller figure will apply to restaurants serving cheaper meals, and the larger one to better-class restaurants. If figures are not available as to the number of meals served, it may be approximated from the number of tables and the seating capacity. When the plan of a building must be used for all information, it may be assumed that a table for four people requires 50 sq. ft. of floor space. This is an average figure; in cheaper restaurants less space will be required, and in expensive ones considerably more.

Assuming a restaurant is 100 ft. long and 50 ft. wide, then its floor area is 5,000 sq. ft. At 50 sq. ft. each, it will be possible to have 100 tables, seating 400 people in all. Allowing for some diners taking less than an hour over their meal, it is possible that 500 meals will be served during the maximum hour. The corresponding hot water consumption will be about 250 gal. For such a building the apparatus of Fig. 3 would be very suitable. The hour before and after the peak hour would require only about half the maximum, so that the 500 gal. capacity over a period of 3 hours given by the apparatus of Fig. 3 would meet all requirements. If instantaneous gas heaters were used three would be needed, each with a capacity for heating 100 gal. of hot water per hour. An electric apparatus would need to have a capacity of 500 gal. of hot water over a period of 3 hours.

In a restaurant the hot water consumption apart from the kitchen will be negligible. In an hotel it may be taken that each person will use 8 gal. of hot water during the maximum hour, excluding the kitchen. Using this figure an apparatus of proper capacity may be designed, as explained under Hot Water Supply: (2).

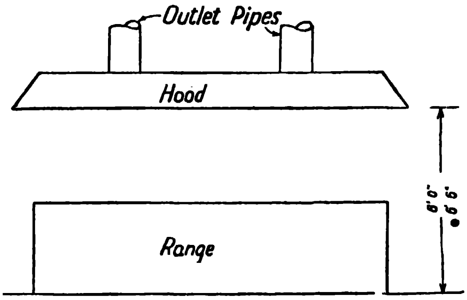
C. VENTILATION

The ventilation of hotels and restaurants may be considered under two heads. Dining-rooms, ballrooms, etc., require almost standard treatment. The kitchen, on the other hand, requires special consideration and it is often difficult to ensure satisfaction. As a first and vital principle all air flow in the building must be from the public parts and into the kitchen. This will prevent cooking smells leaking out into the building. Thus, more air must be extracted from the kitchen than is supplied to it, while in the other rooms the reverse will apply.

The amount of ventilation required in a kitchen will depend on its type. If it is

part of a club or hotel it will probably be underground, and large and complicated meals will be cooked. Here the ventilation will need to be very complete. On the other hand a restaurant serving only light meals, in which the kitchen has plenty of windows and skylights, will need no mechanical ventilation.

Hoods to Ranges, etc. In the larger kitchens most difficulty arises from the ranges, grilles, and similar fittings. These give off a large amount of heat and fumes which are best dealt with by hoods or canopies. These should be constructed of galvanized sheet steel of heavy gauge. Occasionally copper, aluminium or glass



HOTEL: HEATING, HOT WATER, VENTILATION. Fig. 6. Hood over kitchen range: about 2 ft. deep, having clearance of 6 ft. to 6 ft. 6 in.; one outlet pipe is provided to each 6 ft. of length; hood overlaps the range by at least 6 in. all round.

is used, although their only advantage is appearance and they are considerably more costly. The bottom edge of the canopy should be as low as possible, to ensure its catching the majority of the fumes. As shown in Fig. 6, a height of 6 ft. to 6 ft. 6 in. will usually provide sufficient clearance for the heads of people working in the kitchen. The edge of the canopy should be wired to prevent any possibility of cuts to the staff. The canopy should be about 2 ft. deep and overlap the range or griller by not less than 6 in. in all directions.

One outlet pipe should be used for canopies up to about 6 ft.; two pipes for those up to 12 ft. in length, and so on—one pipe for each 6 ft. of canopy.

The quantity of air to be taken from the hood may be found by assuming a face velocity of 50–100 ft. per minute. Assume, for example, a hood 10 ft. long by 4 ft. wide. Its area is 40 sq. ft., and with a face velocity of 50 ft.p.m. the air to be extracted is 40 × 50=2,000 cu. ft. per minute. The size of the pipes or ducts may be found by taking a velocity of about 600–800 ft.p.m. In the example

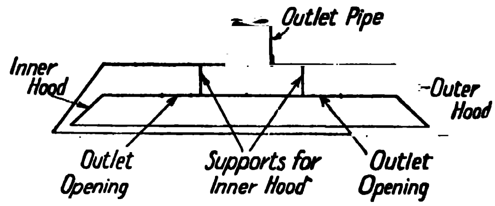


Fig. 7. Double hood for range, to remove larger quantity of air than is possible with single hood of same external dimensions (see text).

above, the hood would need two pipes, as it is more than 6 ft. long. The total area required, taking a velocity of 700 ft.p.m., would be 2,000 ÷ 700 = 2·86 sq. ft., which is equivalent to two pipes each having a diameter of 16 in. If the flow through the pipes is by natural draught, the velocity of flow will depend on the height to which the outlet is raised above the canopy.

The face velocities mentioned above are none too high, and even so involve large air quantities. To overcome this the double hood of Fig. 7 is advantageous. This consists of one hood inside the other, with a gap of 1 in. to 2 in. at the edges. Through this gap an air velocity 400 ft.p.m. to 500 ft.p.m. is maintained, which is high enough to obviate the escape of any fumes from under the canopy. Two holes per pipe connexion (of the same diameter as the pipe in the middle of the inner hood) take care of fumes rising vertically.

Ventilating Calculations. The general ventilation of kitchens should be based on air changes of not less than 30 per hour. For the average kitchen, extract ventilation only is sufficient, with the gratings at high level. Fresh air may be allowed to find its way in by natural means through gratings, windows, etc.

As an example the kitchen of Fig. 8 may be taken, its height being assumed as

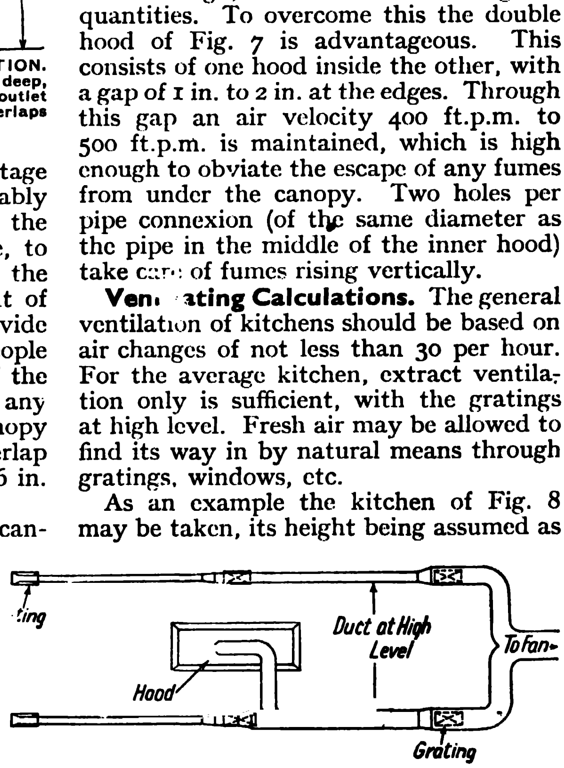
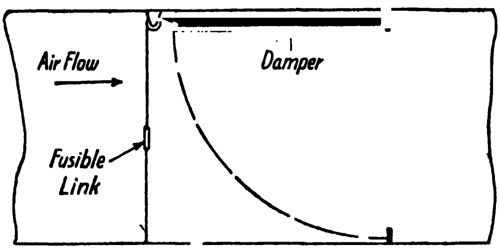


Fig. 8. Typical exhaust ventilation for kitchen: canopy and gratings designed to provide for 30 air changes per hour. For calculations to ascertain sizes of hood and gratings, see text.

10 ft. The volume is 10,000 cu. ft. At 30 air changes per hour there will be 300,000 cu. ft. per hour, or 5,000 cu. ft. per minute to be extracted. If the canopy over the range in the middle is 10 ft. by 4 ft., not less than 2,000 cu.ft.p.m. (cubic feet per minute) must come through the canopy. This leaves 3,000 cu.ft.p.m. to be taken through the gratings. Three gratings evenly distributed on either side of the canopy, making six in all, would be satisfactory. Each grating would then have to handle 500 cu.ft.p.m. The free area of the gratings would be about 2 sq. ft., taking a velocity of 250 ft.p.m. (The necessary area



HOTEL : HEATING, HOT WATER, VENTILATION. Fig. 9. Fire damper in main extract duct for ventilation of kitchen : heavy plate damper hinged at top and held open by chain with fusible link.

of the ducts may be calculated as explained under Duct System). The fan discharge needs care, since it consists of air laden with fumes. It should be in such a position as not to give cause for objections. For this reason it is usual, even if the kitchen is in the basement of a high building, to take the discharge duct from the fan up to the roof.

Ducts. The ducts themselves require a certain amount of attention. They should be of somewhat heavier gauge than usual and be well supported, since they become coated inside with condensed fat from the cooking fumes. For this reason also access doors must be provided to enable the whole of the interior of the ducts to be cleaned. This operation is usually carried out at regular intervals. Sometimes the ducts are insulated with asbestos. This largely prevents the fume condensation, and the ducts require cleaning less often.

It is a wise precaution to fit a fire damper in the main extract duct. One form is shown in Fig. 9. It consists of a heavy plate damper hinged at the top and held open by a wire or chain in which is a fusible link. This link fuses at a temperature of about 150° F., when the chain releases the damper, which falls shut. Air flow up the duct is prevented. Any fire which may start because of the fat in the ducts becoming ignited is not then increased by the air draught.

Mechanical Air Supply. If the kitchen is so badly situated that fresh air cannot get in by natural means, mechanical air supply must be provided. The volume blown in should be not more than three-quarters of that extracted. Two methods may be used: the first is to have inlet gratings at low level corresponding to the extract gratings. Here the air velocity through the gratings should be about 200 ft.p.m. The second method is to have ducts at high level with a number of nozzles of 2 in. or 3 in. diameter. The air is blown through these at a velocity of about 1,000 ft.p.m., and directed to the working plane. Whichever method is adopted, the air should be efficiently filtered.

The average small kitchen can be quite adequately dealt with by a propellor fan fixed at high level on an outside wall. An air change of 30 times per hour should be used and care should be taken that the fan discharge is not in a direction likely to cause annoyance from smells.

The ventilation of restaurants, dining-rooms, etc., is exactly similar to that of other public rooms. The general article dealing with the subject should therefore be consulted.

HOT WATER. Water expands when heated, and its density decreases. At 40° F. 1 cu. ft. weighs 62·425 lb.; at 70° F., 62·313 lb.; at 200° F., 60·081 lb. [*Note.* These values are taken from Table I, Heating Chart *f.p.* 505, which gives the working basis for calculations in this Encyclopedia. For further information *see under* Density; *refer also* to Water & Water Supply: (1)]. As a result of this difference in density, warm water rises, and in any closed and connected system when heat is applied at the lowest point a circulation is set up. In such a system a definite pressure is produced, the pressure being stated in inches of water. This pressure is the motive force in the gravity flow hot water supply system.

Gravity flow is produced by the difference in weight of the column of hot water in the supply risers and the column of cooler water in the return risers. The motive force is small and is influenced directly by the temperature difference of the water in the

two columns and the height of the columns. Examples are given in Table I. For practical calculations *see* under Heating: (1) & (2).

TABLE I. Circulating Pressure in Hot Water Supply System.

	Circulating head in inches of water per foot head				
Return temp. °F.	Flow temperature in °F.				
	200	180	160	140	120
200	—	—	—	—	—
180	0·096	—	—	—	—
160	0·181	0·086	—	—	—
140	0·258	0·163	0·077	—	—
120	0·324	0·230	0·145	0·068	—
100	0·383	0·288	0·201	0·125	0·057

Note. An extended table of circulating pressure calculated on a different basis appears on the Heating Chart facing page 505.

With a return temperature of 120° F. and a flow of 200° F. and a head of 30 ft., the circulating head is $30 \times 0{\cdot}324 = 9.72$ in. of water, which is very small and only sufficient for domestic supply purposes. Forced circulation is obtained by means of a circulatory pump placed in the return main close to the heater. (*See* Accelerator.)

Expansion. Since water diminishes in density (and increases in volume) upon being heated, provision has to be made in certain heating and hot water apparatus for this expansion. In open type hot water installations an expansion pipe is fitted for the purpose, often serving also as the cold feed pipe. Water can make its way up this pipe from the system. The cold feed tank thus functions as an expansion tank. In hot water heating systems the expansion tank is arranged differently (*see* Heating). No water is drawn from the system, and so there is merely the "make-up" for evaporation to be provided. It will be seen that only enough water to float the ball of valve is allowed normally to enter, and there is ample capacity for water expansion between this water level and the overflow level. Usually one-twentieth of the water content of the system is taken as the amount to be provided in this way for expansion. (*See* Cold Water Supplies; Expansion Pipe.)

Pressure and Temperature. The boiling point of water at standard air pressure (1 atmosphere) is 212° F. or 100° C. Increase of pressure raises, and decrease of pressure lowers, the temperature of the boiling point. (*See* Table II.) In all hot water systems the water in the boiler is under a pressure greater than atmospheric. In closed systems the pressure may be very considerable. There is a great static pressure in high buildings.

TABLE II. Relation of Temperature of Water to the Boiling Point.

Pressure		Boiling Point	
Atmospheres	lb. per sq. in.	Degrees C.	Degrees F.
0·125	1·8	50·5	122·9
0·25	3·7	66·0	150·8
0·5	7·4	82·0	179·6
1·0	14·7	100·0	212·0
2·0	29·4	121·0	249·8
3·0	44·1	135·0	275·0
4·0	58·8	145·0	293·0
5·0	73·5	152·2	306·0
10·0	147·0	180·0	356·5
20·0	294·0	213·0	415·4

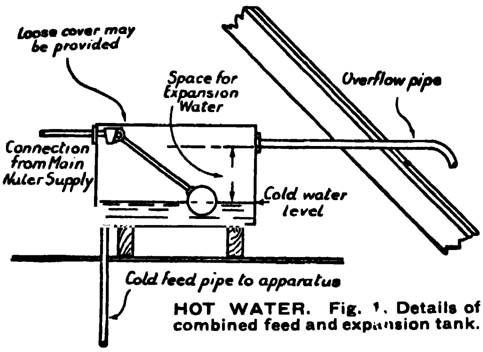
With a head of water in the supply tank of 34 ft. (1 atmosphere), the pressure on the water in the boiler is 2 atmospheres and the boiling point approximately 250° F. This means that it is possible to have the water in the boiler and at a tap at a temperature higher than 212° F., and the water cannot change to steam because of the pressure on it. When the tap is turned on the pressure is suddenly released and the water boils instantaneously.

The bursting of a boiler in such circumstances may have serious effects, and safety valves are fitted. The expansion pipes of domestic hot water supply systems should be protected against frost to prevent them becoming sealed. The effect of additional head of water is shown below.

Head of water in feet.	Boiling point °F
0	212
10	218
20	236·2
30	246
40	254·5
50	261·5
60	268·5
Boiler	

Water under pressure at a temperature of, say, 293° F. (pressure 4 atmospheres) contains a much greater quantity of heat than the same weight of water at 212° F., an increase of about 40 per cent. This

increased "heat storage" capacity is made use of in heating systems. High pressure hot water systems are sealed hermetically or by a heavily loaded valve.



HOT WATER. Fig. 1. Details of combined feed and expansion tank.

The water is pumped in under pressure. The pipes are of small bore and the heating coil is in an enclosed furnace kept at a temperature of about 300° F. An expansion chamber must be fitted and allowance made for the dissolved gases in water which are driven out during heating. An anti-freeze mixture is often used to prevent frost damage.

Water which contains dissolved solids boils at a higher temperature than pure water. Salt water boils at 219° F.

Stratification. A well-designed supply system should give the hottest water available in the least time. The heated water from the boiler should be delivered at a point from which it can be immediately drawn and there should be no mixing of the hot water with cold water. There should be "stratification" in the storage tank or cylinder: that is, a clear line of demarcation between the hot water and the cold water. To attain this:

(1) The cylinder or tank should be as near boiler as possible, to give minimum of resistance to circulation. (2) The flow pipe from boiler should be high up on boiler, and the return be taken to bottom of cylinder. This avoids mixing the hot and cold water and gives as quickly as possible a layer of hot water at top of cylinder available for drawing off before the whole cylinder of water is heated. (3) The cold supply should be connected either to bottom of cylinder or to the return pipe from cylinder to boiler, to prevent mixing with the hot water at the top of the cylinder.

Where draw-off pipes to baths, sinks, airers, etc., are long, a "secondary" circulating main (shown dotted in Fig. 2), with gravity circulation, should be added so as to avoid large quantities of cold water being drawn before hot water is obtained. The return main of secondary circulation should connect not lower than one-third down from the top, so as to prevent a flow of cold water being drawn into the return pipe when a tap is opened. With correct design of size of pipes and allowance for frictional resistance, etc., it is frequently possible to detect by touch when the cylinder is not insulated, the line of demarcation between hot and cold water at any instant to within about ½ in. There is no transference of heat from one to the other except by conduction, and this is a very slow process as water is a poor conductor.

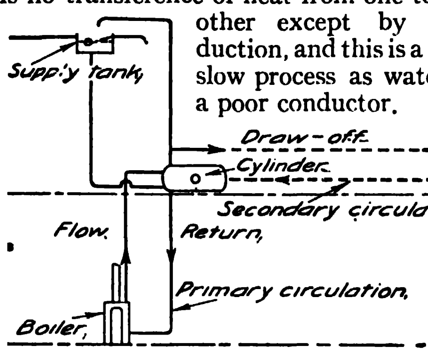


Fig. 2. Hot water supply system with primary circulation to cylinder and secondary circulation to taps, to avoid the necessity of drawing off cold water from long lengths of "dead" pipe before hot water will flow.

The primary circulation from boiler to cylinder admits cold water through boiler and forces hot water into top of cylinder. The dividing line between hot water and cold water is gradually lowered. When hot water is drawn off from the upper portion, cold water enters at the bottom of cylinder and pushes hot water upwards, thus raising the line of demarcation.—*Norman Howdill, B.Sc., A.I.Struct.E.*

HOT WATER FITTER. A central hot water-supply system may be a part of a central heating system or may be a separate installation. If combined with heating, specification clauses will be included under that heading, but if separate, is dealt with in a special section, as indicated by the sample below.

General. The contractor is required to make the installation according to instructions and plans, to test it, leave it in working order, and be responsible for repairs of faults arising within six months.

Heating Device. The source of heat may be a range, an open fire, a coal, coke, anthracite, or oil-burning boiler, electric

or gas apparatus. If a fire, the construction of the fireplace must be described, but the brickwork will be carried out by the bricklayer. The boiler, gas or electric apparatus is specified by make, capacity, and any special fittings.

Cylinder. The type, capacity, strength and fittings are described; the position, fixing and connexions detailed.

Piping. The sizes, lengths, and materials and finishes of all pipes and fittings, and any insulation are given. Special mention is made of piping for towel airers and linen cupboard coils. The system is specified in detail. The hot water fitter is required to provide stop-cocks and unions for plumber's final connexions within 2 ft. of every tap.

Hard Water Cylinder. Where required, type, capacity and fixing are specified.

Testing. To be done to the satisfaction of the architect, engineer or builder.

HOT WATER SUPPLY: (1) PRINCIPLES OF DESIGN

By W. E. Fretwell, M.I.Mech.E., P.P.I.H.V.E., F.I.S.E.

In the first article of the Group, an authority of the highest rank explains the principles of design for Hot Water Supply, including a section on Rating of Dual-Purpose H.W. Boilers. Valuable original data and formulae are given, with worked-out examples. For cold water supplies to H.W. systems see Cold Water Supplies. See *also* Hot Water. The arrangement of the rest of the series is as follows:

The fundamental object of every domestic hot water installation is to provide an adequate supply and outflow of hot water at all hot water taps likely to be open simultaneously.

Domestic hot water systems may be classified as (1) instantaneous systems and (2) storage systems.

An *instantaneous hot water system* is one in which water is heated as it flows through the heater on its way to an open tap or taps. The water heating medium may be electricity, gas or steam. The thermal capacity of an instantaneous water heater should be sufficient to raise to the desired temperature the quantity of water required during the hot water peak demand period. The external surface of an instantaneous hot water system is smaller, the resultant heat losses less, and the quantity of heat energy used lower than for any other hot water supply system.

When installing an instantaneous hot water system, care should be taken to comply with the appropriate water authority's regulations. Many water supply authorities' regulations have been since 15th June, 1950, extended or modified to conform to M.O.H. Model By-Laws Series XXI covering "Prevention of waste, undue consumption, misuse or contamination of water." Stationery Office, (3d.).

A *hot water storage system* is one in which pre-heated water is stored in one or more vessels for subsequent use. The combined heating power of the "boiler" and hot water storage capacity should be capable of providing an adequate quantity of warmed water for use during the peak demand period.

Terms and Definitions. Reference may here be made to certain accepted data and other practical terms affecting the design of hot water supply installations, together with some simplified formulae.

Temperature. In accordance with English engineering practice, temperature is expressed herein in degrees Fahrenheit.

Water Heater. This includes boilers, calorifiers and all other types of heaters installed to warm water and employing electricity, gas, oil or solid fuel.

Cold Water Temperature. When applied to domestic hot water installations the term means the temperature of unheated "feed water." In Britain the temperature of water supplied by public water supply authorities varies from about 42° in winter to 65° during summer. Water drawn from privately owned wells varies in temperature from about 40° to 50°. The actual temperature of water in a cold water storage cistern will depend upon whether or not it absorbs or gives up heat during storage. For hot water supply calculations it is customary to assume a cold water temperature of 50°.

Cold Water Feed Cisterns. In Britain most water supply authorities by their regulations insist upon the provision of cold water cisterns for storing water for hot water installations and sanitary fitments. The only general exception to this regulation is in respect to drinking water taps, fire hydrants, car washing and garden hydrants. The capacity of a cold water storage cistern or cisterns should be sufficient to ensure an undiminished outflow of water to all fitments open at the same time. The required capacity of the cold water cistern will also depend to a large extent upon the rate at which water enters it; this in turn depends upon the water pressure available, the diameter of supply service and size and type of ball valve.

All ball valves offer considerable resistance to flow of water through them, and a much larger inflow is obtainable by providing two ball valves. Many water supply authorities insist that where an outlet on a cold water storage cistern is common to both hot and cold water outflow services, the cold water shall be at a prescribed height above that supplying the hot water system, the reason being to ensure, so far as possible, undiminished supply of water to the hot water system.

Hot Water. The term "hot water" may be applied to water at any temperature between, say, 100° and boiling point, but for domestic use a temperature of about 150° F. is customary.

Mixed Water Temperature. In 1931 the present writer in a paper read at a meeting of the Institution of Heating and Ventilating Engineers gave the following simple formulae for calculating the temperature of hot and cold water mixtures:

M − C = Parts of hot water.
H − M = " " cold water.
Where C = Cold water temperature.
M = Mixed " "
H = Hot " "

Example.—Calculate the quantity of water at 45° and 140° F. respectively to produce 1,000 gal. at 105°.

105 − 45 = 60 parts of hot water.
140 − 105 = 35 " " cold water.
Total 95 parts.

Hot water required: $\frac{1,000 \times 60}{95} = 632$ approx. gal.

Cold water required: 1,000 − 632 = 368 gal.

The resultant temperature after thoroughly mixing two or more quantities of water may be calculated by adding together the product of the weight in lb. and temperature of each and dividing the whole by the total weight of water in lb.

Example.—Calculate the resultant temperature of mixing the following quantities of water: 500 lb. at 100°, 100 lb. at 120° and 200 lb. at 50°.

Product of weight and temperatures:

500 × 100 = 50,000
100 × 120 = 12,000
200 × 50 = 10,000
800 72,000

Final temperature of mixed water:

$\frac{72,000}{800} = 90°$ F.

Definitions of Fitments. The following terms are applied to the various fitments which require a supply of hot water:

Slipper Bath. In public bath establishments the term is employed to describe the ordinary taper or parallel bath. These baths are of the same shape as those installed in private houses and the like, and the term "slipper bath" is employed hereafter to differentiate them from other types.

Plunge Baths. These usually form part of Turkish bath and Russian or vapour bath equipment and are widely used for ablutionary purposes in sports pavilions. They are generally sunk in the floor to a depth of three or four feet, the surfaces being tiled or rendered smooth, and are usually large enough to accommodate some 5 to 20 persons.

Shower Baths. Shower baths usually take the form of a spray or rose fixed over a slipper bath, foot bath or suitable floor draining device. The temperature of the water from the rose is controlled by a mixing valve to which both hot and cold services are connected.

Lavatory Basins. These refer to the ordinary basin as fixed in bathrooms, dressing rooms, bedrooms, etc.

Sinks. These refer to the ordinary household sink. There are, of course, many types of special sinks for washing-up purposes, etc.

Other Fitments. Bidets and other special fitments are frequently installed, and the hot water engineer should himself ascertain the probable temperature and quantity of water to be provided for these.

Hot Water Requirements of Various Fitments

Fitment.	Temperature Fahrenheit.	Quantity mixed water per average user. Gal.
Slipper bath ..	100°–110°	30
Plunge bath ..	100°–110°	According to size of bath
Showers	98°–105°	10
Lavatory basins	100°–110°	3
Ordinary scullery sinks ..	110°–120°	5
Sinks for greasy articles	120°–140°	5

A. SIZE OF APPARATUS AND QUANTITY OF HOT WATER TO BE PROVIDED

The thermal capacity of the water heater and the amount of hot water storage, if any, constitute what may be termed the " size " of the apparatus. The quantity of hot water required during the busiest period of the busiest day constitutes the hot water peak demand factor. This factor depends to a great extent upon the number, size and type of bath and other hot water fitments installed, the class of premises in which they are fitted, and the number and ablutionary habits of its occupants. The higher the class of house, flat, boarding house and hotel, the greater the number of baths, basins and other like fitments installed. It should be borne in mind that the larger the number of ablutionary fitments installed in relation to occupants, the greater is the inducement to use them; and although the average quantity of water used per fitment may be less the quantity per person is larger.

In practice, the actual size of hot water apparatus to be provided should be based on the following factors:

1. The number and vocation of the occupants of the premises.
2. The ratio of the number of baths and other fitments to occupants.
3. The probable number of pre-breakfast baths to be provided.
4. The duration of the active pre-heating and peak demand period and the hour at which it commences.

The incidence of these factors upon the " size " of apparatus will now be examined.

The vocation of occupants affects the hot water peak demand period. For example, a large number of professional and business people having offices in town reside at the coast and other places distant. The time taken up by ablutions, breakfasting and travelling necessitates their rising at a relatively early hour and the hot water peak demand period is, in consequence, both short and heavy. Where the ratio of the number of baths to occupants is small, the tendency is for pre-breakfast bathers to hurry and so enable as many as possible to partake of a bath before setting out for the day. The general custom in calculating the size of apparatus to be installed is to ignore the number of occupants and to base the " size " of apparatus on the number and type of installed hot water fitments. This practice may lead to serious complaints.

Imagine a hotel or boarding house where the adult occupants number one hundred, the number of installed baths being, say, ten. Suppose the pre-breakfast demand period to be 40 minutes. Because of the paucity of installed baths the bathers would probably occupy a bathroom not more than, say, 20 minutes. On this assumption and starting from zero, a second bath would follow in 20 min., a third in 40 min., and so on at 20-min. intervals. For ten bathrooms the number of those able to take a bath during 40 min. would be thirty. Based on a commonly used hot water storage factor of 20 gals. per bath, the hot water required for 10 installed baths would be 200 gal., whereas the hot water demand for baths alone would probably approximate to 15 gal., at 150° or higher per bather, making a total for baths alone of 450 gal. of hot water during 40 min. In addition to hot water for baths, all non-bathers would almost certainly use a lavatory basin during the pre-breakfast hour or thereabouts; men bathers would also use a lavatory basin when shaving.

Calculating the Hot Water Demand. Although it is impossible to predetermine the quantity of hot water used during a peak demand period, the size of apparatus should be based on the number and type

of hot water fitments installed and the potential users thereof. No hard and fast rule will meet all cases, and the hot water engineer must employ his common sense and install a plant of sufficient size to meet all probable requirements. The following examples are intended to assist in this direction.

Example 1. Small private house. Consider a small private house in which there is installed one bath, two basins and one sink. Assume the cold water temperature to be 50°, the peak demand period 30 minutes and the active pre-heating period 1½ hours.

Bath. Assuming two baths to be required during the peak demand period and that each uses 30 gal. of warmed water at 105°, the amount of heat withdrawn with the warmed bath water would be 60 gal. = 600 lb. × (105 − 50) = 33,000 B.Th.U.

Basins. Each user of a basin may be presumed to use 3 gal. of water at, say, 105°. Allowing that four persons use basins during the peak demand period, the amount of heat withdrawn with the warmed water is 12 gal. = 120 lb. × (105 − 50) = 6,600 B.Th.U.

Sink. Allowing that, say, 4 gal. of water at 120° are withdrawn at the sink during the pre-heating period and none during the peak demand period, the amount of heat withdrawn with the warmed water is 4 gal. = 40 lb. × (120 − 50) = 2,800 B.Th.U.

Heat Losses. Assume that from the beginning of the active pre-heating period to the end of the peak demand period, heat losses from the exposed surfaces of the installation amount to 3,300 B.Th.U. per hour, making a total for two hours of 6,600 B.Th.U.

Size of Water Heater. The theoretical thermal capacity of this should be based on the number of heat units—in the form of warmed water—withdrawn from the installation from the beginning of the active pre-heating period to the end of the peak-demand period (plus the amount of heat given off from the exposed surfaces of the installation).

The required "size" of heater for Example No. 1 is calculated as follows:

		B.Th.U.
Baths, 60 gal.	= 600 lb.	
Basins, 12 gal.	= 120 lb.	
	= 720 × (105 − 50)	= 39,600
Sink, 4 gal.	= 40 lb. × (120 − 50)	= 2,800
Heat losses, 2 hours at 3,300		= 6,600
	Total	49,000

For a combined pre-heating and peak demand period of 2 hours the heater must produce an average of 49,000 ÷ 2 = 24,500 B.Th.U. per hour.

As it is impossible to withdraw, at a useful water temperature, the whole of the heat absorbed by the water, it is desirable to increase the "size" of heater by, say, 30 per cent.; therefore the minimum size of heater should be 24,500 × 1·3 = 31,850 B.Th.U. per hour.

Note. In this calculation the quantity of heat absorbed by the installation material is ignored.

Amount of Heat Storage to be Provided. The quantity of heat to be stored is that which is unused during the pre-heating period. For Example No. 1, the difference between the heat input and that withdrawn and lost during the pre-heating period is:

		B.Th.U.
Heat input, 1½ × 24,500		= 36,750
Heat withdrawn, 4 gal. = 40 lb × (120 − 50)	= 2,800	
Heat losses, 1½ hrs. × 3,300	= 4,950	
	——	= 7,750
	Difference ..	29,000

Storage must be provided for 29,000 B.Th.U.

Assuming a mean hot water storage vessel content temperature of 150° with cold feed water at 50° the equivalent capacity of storage is 29,000 ÷ (150 − 50) = 290 lb. or 29 gal. As it is impossible to withdraw, at a useful water temperature, the whole added heat content of a hot water storage vessel, it is desirable to add, say, 50 per cent. to its required theoretical capacity. For Example No. 1, the storage vessel should hold 29 × 1·5 = 43·5 gal.

These calculations presuppose an initial water content temperature of 50°. Where the boiler fire is burning continuously the initial temperature of the installation preceding the active pre-heating period would exceed 50°.

Whether in "sizing the heater" it is desirable to take advantage of a higher initial water temperature is for the heating engineer to decide.

Example 2. Calculate the size of heater and hot water storage vessel to be provided where, for certain given conditions, the quantities of hot water to be provided are as follows:

Cold water temperature, 50° F.
Pre-heating period, 1½ hours.
Peak demand period, 1 hour.
150 baths at 30 gal. each at 105°.
500 basins at 3 gal. each at 105°.
Sinks: Pre-heating period, 100 gal. at 120°.
Peak demand period, 100 gal. at 120°.
Heat losses from installation, 10,000 B.Th.U./hour.

Quantity of heat required:	B.Th.U./hr.
Baths: 150 × 30 = 4,500 gal. or 45,000 lb. × (105 − 50)	= 2,475,000
Basins: 500 × 3 = 1,500 gal. or 15,000 lb. × (105 − 50)	= 825,000
Sinks: 200 gal. or 2,000 lb. × (120 − 50)	= 140,000
Heat losses = 2½ × 10,000	= 25,000
	3,465,000

For a combined pre-heating and peak demand period of $2\frac{1}{2}$ hours, the heater must produce an average of $3{,}465{,}000 \div 2\frac{1}{2} = 1{,}386{,}000$ B.Th.U. per hour. Adding 30 per cent. to this gives 1,801,800 B.Th.U., which then represents the " size " of heater to be installed.

Amount of heat storage to be provided:

		B.Th.U.
Heat input, $1\frac{1}{2} \times 1{,}386{,}000$		= 2,079,000
„ output, 100 gal. = 1,000 lb. × (120 − 50)	= 70,000	
Heat losses, $1\frac{1}{2} \times 10{,}000$	= 15,000	
		85,000
Difference		1,994,000

Assuming a mean hot water storage content temperature of 150°, cold water 50°, the equivalent capacity of storage is 1,994 gal. Adding 50 per cent. gives 2,991 or, say, 3,000 gal. and then represents the hot water storage to be provided.

B. HOT WATER STORAGE SYSTEM

The simple system shown on the right, will serve to explain the principles and functions of various parts, most of which are common to all hot water storage installations.

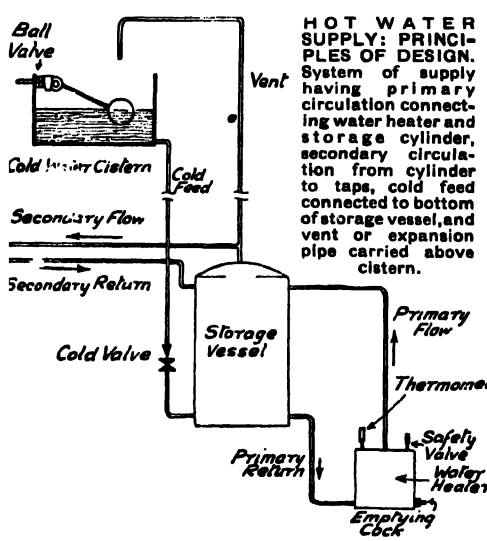
Water Heater and Storage Vessel. The size of the water heater and the capacity of the storage vessel should be computed in accordance with the examples just given.

The storage vessel may be of any shape, provided it will safely withstand the internal water pressure and stresses to which it may be subjected. Rectangular tanks will not withstand a very high internal water pressure without distortion, and for this reason they should seldom be used where the head of water above them exceeds about 10 ft. Cylindrical tanks, or cylinders as they are then termed, having domed or dished ends are fundamentally stronger and are able to withstand much higher internal pressures. Where practicable, it is better to provide what is termed a vertical hot water cylinder (*i.e.* one where the height exceeds its diameter). With such a cylinder the area of contact between the inflowing cold water and the stored hot water is less and its hot water content can be withdrawn with less " mixing."

Cold Water Feed Cistern. Wherever practicable, this should be placed well above the highest hot water branch connexion serving draw-off points, the advantage being that the greater water pressure thus obtained facilitates the outflow of water and assists in reducing the diameter of all pipework other than the primary flow and return and vent pipes. The capacity of the cistern should ensure that it will accommodate the expanded hot water representing about 1/20th of the content of the hot water system, and that it is not depleted during the heaviest withdrawal of water. A larger cistern is required where it has, in addition, to serve other fitments.

The Metropolitan Water Board require that every storage cistern shall have a capacity of not less than 50 gallons and, if intended to be used as a feed cistern as well as a storage cistern for other purposes, shall be of a capacity of not less than 80 gallons. It should be fitted with a close fitting cover to exclude dirt and be insulated against damage from frost. The supply pipe should be of adequate diameter. All ball valves offer considerable resistance to flow of water; in some cases it is desirable to provide more than one ball valve. An overflow of adequate diameter should be provided.

Cold Water Feed Pipe. The diameter of this controls the rate of outflow from the apparatus. It should



HOT WATER SUPPLY: PRINCIPLES OF DESIGN. System of supply having primary circulation connecting water heater and storage cylinder, secondary circulation from cylinder to taps, cold feed connected to bottom of storage vessel, and vent or expansion pipe carried above cistern.

ensure that during the heaviest outflow the level of water in the apparatus is always higher than the uppermost hot water service junction. It should be fitted with a full-way stopcock and be connected to hot water storage vessel as close to bottom as possible, preferably at the side (as in diag. above), so as to deliver

water horizontally; this avoids the risk of entering water boring its way into and cooling the hotter water. Where, as in the case of horizontal cylinders, it is often necessary to join the bottom, the end should be fitted with a tee piece placed lengthwise down the vessel, which then avoids the risk of inflowing water swirling up the sides and mixing with hotter water. A " dip " (*i.e.* an inverted siphon) is sometimes provided at the point where it joins the apparatus and is of no practical use; it provides a pocket for accumulating debris and then retards the flow of water. It will not, as often claimed, prevent warm water from backing up into the cold water cistern.

The feed pipe should serve the hot water apparatus only, and not more than one such pipe should deliver water into the system.

Primary Flow and Return. These members constitute the primary circuit. The diameter of the pipes should be large enough to ensure free circulation of water. An advantage of installing large-diameter pipes is that the effect of stoppage by " furring " or incrustation, if any, is longer delayed. The disadvantage of excessively large piping is that the water content of the apparatus may pass through the boiler so fast as to necessitate repeated re-circulation before any water reaches a useful temperature. The outflow end of the primary flow should join the storage vessel as close to the top as possible, so as to deliver hot water where it is most wanted.

The return should join the vessel as close to the bottom as possible so as to ensure the whole content being in circulation.

Stopcocks. Where two or more boilers are installed, stopcocks are sometimes fitted to the interconnecting pipework, the object being to avoid emptying the apparatus or stopping its working if it should be necessary to clean out or effect repairs to one or other of them.

Such valves are a potential source of danger and are best avoided wherever practicable. They should never be closed even while there are dying embers on the firegrate, and should be padlocked.

In addition to a safety valve, each such boiler should be fitted with an open-vent pipe. Means should be provided to take apart the pipework; the most satisfactory method for this purpose is to install bolted flanged connexions.

Open Vent Pipe. The function of this is to prevent hermetic sealing of the apparatus and to permit the automatic escape of air and easy filling. An open vent pipe is more sensitive to, and will better relieve pressure than, any safety valve, although the latter should be provided in addition.

Every vented hot water apparatus is in effect a U-tube in which the cold water column forms one leg and the hot water vessel and vent pipe the other. The pressure of these connecting columns will exactly balance.

Owing to the difference in density, the water in the hotter column will stand slightly above the water level in the supply cistern; the actual difference may amount to about half-inch for each vertical foot of column between the water level in the supply cistern and the point where the cold feed joins the apparatus. The vent pipe should be carried up high enough to prevent water outflowing. An allowance of, say, 1 in. per ft. of column above the top of the supply cistern is usually sufficient. Where the water content of the apparatus is permitted to boil, there is always a risk of water being ejected from the vent pipe. The water in a domestic hot water supply apparatus should not be allowed to boil.

The vent pipe on a hot water supply system is often wrongly described as an expansion pipe. (*See* Expansion Pipe.) Expanded water enters the cold water supply cistern through the cold feed pipe, the latter serving a dual purpose.

The vent pipe should preferably terminate over the cold water supply cistern. Where it is necessary to carry it outside, care should be taken to protect it against frost, and the open end should be arranged so that any discharge will not cause injury to persons or property. The diameter of the vent pipe should not be less than three-quarters of an inch.

Secondary Circuits. The purpose of secondary circuits is to avoid having to withdraw more than a negligible amount of cold water before hot outflows, and also to comply with the regulations of the Metropolitan Water Board or other supply companies. When a tap

on a secondary circuit is opened, water will flow towards it from both ends, and they should, therefore, join the storage vessels where the water is hottest—*i.e.* at or near the top (*see further under* Secondary Circulation).

Safety Valves. Every apparatus should be provided with a safety valve having metal-to-metal contact; it should preferably be placed directly on the boiler, and should relieve pressure at, say, 10 lb. above the nominal head pressure. Each apparatus should be provided with an emptying cock, thermometer and, when practicable, an automatic damper regulator.

The elementary principles of design explained here should be incorporated in every hot water storage installation. For layout, etc., *see* Hot Water Supply: (2).

C. RATING OF DUAL-PURPOSE HOT WATER BOILERS

It is common knowledge among plumbers and heating engineers that a dual-purpose hot water boiler is given two different catalogue ratings, depending upon whether it is to be used as a domestic hot water boiler or as a central heating boiler; the reason for giving two ratings to the same boiler is not, however, generally understood.

That no part of a boiler plate approaches the temperature of the boiler fire or gas flame may be shown by sticking a strip of gummed paper on the bottom of a kettle from which soot has first been removed. If the kettle containing water is placed over a gas ring, it will be found that the water may be boiled without charring the paper. This experiment indicates the presence on the bottom surface of the kettle of a thin semi-stagnant film of gas through which heat must pass before reaching the metal itself. The presence of the film of gas accounts for the great difference in temperature between that of an incandescent fire in the boiler furnace and the boiler plate separating it from the boiler water. In the case of hot water boilers the temperature of the boiler plate —assuming it to be free of scale, which might cause over-heating of the metal— is unlikely to exceed that of the boiler water by more than 10° F.

Before proceeding with thermal calculations it is essential to clearly understand the meaning of certain terms and symbols employed therein.

Thermal Conductivity (symbol k). Thermal conductivity of a homogeneous material is the rate of heat flow in B.Th.U. per hour, under steady conditions per sq. ft. per inch thickness for a difference in temperature of one degree F., in a direction perpendicular to the area.

The suffix 1, 2, 3, 4, when attached to k, in the form k_1, k_2, k_3, etc., indicates the conductivity of successive layers of different materials.

Thermal Resistivity is the reciprocal of thermal conductivity and is $\frac{1}{k}$. It is the resistance to flow of heat through one inch thickness of material for the transmission of one B.Th.U. per sq. ft. per hour.

Total Resistance (symbol R). When heat flows from one medium to another through one or more intermediate resistances, the total resistance to heat flow is the sum of the individual resistances through which the heat flows, in series.

For heat flow under the conditions of the above definition the transmittance is the reciprocal of the total resistance, viz. $\frac{1}{R}$.

Overall Coefficient of Heat Transfer (symbol U). When heat flows from one medium to another, through one or more intermediate resistances, the transmittance of the system is equal to the rate of heat flow in B.Th.U. per sq. ft. per hour, divided by the difference in the temperature of the two media. This is commonly called the overall coefficient of heat transfer "U" and is the reciprocal of the total resistance, viz. $\frac{1}{R}$. hence $U=\frac{1}{R}$.

Thickness (symbol L). The letter "L" is used to indicate the thickness in inches of the individual material considered. The suffix 1, 2, 3, etc., when attached to L in the form L_1, L_2, L_3, etc., indicates the thickness in inches of successive layers of materials.

The expressions $\frac{L_1}{k_1}$, $\frac{L_2}{k_2}$, $\frac{L_3}{k_3}$, etc., express the thermal resistance of each successive layer of material, the symbol R being used to express the sum of these resistances.

Calculation of Heat Transmission Through Boiler Plates. The whole of the heat received by the circulating water from the boiler furnace must, perforce, be transmitted through the boiler walls. The boiler-wall separating the furnace from the circulating water is, in effect, a composite structure of successive layers of material. On the furnace side of the boiler plate there will be a layer of soot and a semi-stagnant film of gas, the thickness of the latter—according to Prof. W. E. Dalby (Proc. Inst. Mech. Eng. 1909)—being approximately 1/40 in. On the water side there will, in all probability, be a layer of scale of uncertain thickness and conductivity and finally a semi-stagnant film of water, the thickness of which is taken herein to be 1/100 in.

These successive layers, including the boiler plate, make up the composite boiler wall. The rate of heat flow from boiler fire to boiler water may be calculated from the equation :—

$$U = \frac{1}{R} = \frac{1}{\frac{L_1}{k_1} + \frac{L_2}{k_2} + \frac{L_3}{k_3} + \ldots\ldots}$$

Where U = overall coefficient of heat transfer.

L_1, L_2, L_3, etc. = thickness in inches of each successive layer.

k_1, k_2, k_3, etc. = thermal conductivity of each successive layer.

R = Total thermal resistance,

$$= \frac{L_1}{k_1} + \frac{L_2}{k_2} + \frac{L_3}{k_3} + \ldots\ldots$$

Using this equation, the overall coefficient of heat transfer "U" for a $\frac{3}{8}$ in. thick cast-iron hot water boiler is as follows :—

Substance	Thickness	Thermal Conductivity (k) B.Th.U./sq.ft. /deg. F./in./hr.	Thermal Resistance $\frac{L}{k}$
Gas film	$L_1 = \frac{1}{40}'' = 0{\cdot}025''$	$k_1 = 0{\cdot}15$	0·1667
Cast iron	$L_2 = \frac{3}{8}'' = 0{\cdot}325''$	$k_2 = 480$	0·0008
Water film	$L_3 = \frac{1}{100} = 0{\cdot}01''$	$k_3 = 4{\cdot}0$	0·0025
			R = 0·1700

$U = \frac{1}{R} = \frac{1}{0{\cdot}17} = 5{\cdot}9$ or, say, 6·0 B.Th.U. per sq. ft. per hour per degree difference Fahr.

This calculation gives the total resistance to flow of heat as 0·17, of which the gas film accounts for 0·1667 or 98 per cent of the whole, implying that the rate of transfer of heat from boiler fire to boiler water is controlled almost entirely by the thermal resistance of the semi-stagnant gas film.

Boiler Furnace Temperature. The temperature of a furnace may be judged approximately by the colour of the flame as follows :—

Faint red	960° F.
Dull red	1,290° F.
Brilliant red	1,470° F.
Cherry red	1,650° F.
Bright cherry red	1,830° F.
Orange	2,010° F.
Bright orange	2,190° F.
White heat	2,370° F.
Bright white heat	2,550° F.
Brilliant white heat	2,750° F.

"Mechanical World" Year Book 1951.

For an overall coefficient "U" of 6·0 B.Th.U. per sq. ft. per hr. per degree Fahr., the theoretical difference between furnace and water temperature required to produce the boiler ratings in the first column of the following tabulation, may be calculated by dividing the rating by the above-stated overall coefficient.

TABLE

Boiler rating B.Th.U. /sq. ft./hr.	Overall Coefficient "U"	Rating divided by "U"	Assumed boiler water Temp. °F	Required Furnace Temp. °F.
10,000		1,667	100	1,767
7,000		1,167	100	1,267
4,400		750	160	910

Boiler Rating and Firing Period. Boiler rating is related to the firing period, *i.e.* the interval between "refuelling" the boiler. Ideal domestic hot water boiler ratings depend upon the size and type of the boiler, the fixing periods for which vary between about two and three hours as against six to seven hours for central heating boilers. It will be readily understood that the rate of heat transfer is related to the weight of fuel consumed over a given period. To maintain a furnace temperature of around 1,800° F. is impracticable, wasteful of fuel and, with coke fuel in particular, pre-disposes to formation of clinker.

It is, however, both practicable and convenient to let the fire in a hot water boiler go "all out" for short periods to satisfy a sudden demand for hot water; it also avoids the installation of an over-large boiler with the consequent risk of overheating the water content of the system.

In conclusion it should be understood that in practice heat produced by combustion of fuel in the furnace is transmitted

to and through the boiler heating surface by :—

1. Radiation from the fuel bed and flame,
2. By contact between the boiler surface and heated gas in the form of convection, and
3. By conduction through the various media.

Transfer of heat by radiation (*q.v.*), which plays so important a part in the transfer of heat, is too complex a subject for discussion in this brief article. Deductions to be drawn from the foregoing calculations apply only to the type of hot water boiler under discussion and the firing periods usually employed.

The only practicable way to increase the rating of a hot water boiler to any considerable extent is to raise the temperature of the fire, which, in turn, entails more frequent attention to the boiler.

HOT WATER SUPPLY: (2) LAYOUT AND INSTALLATION

By L. C. C. Rayner, A.I.E.C.

After dealing with general considerations governing the successful functioning of hot water supply, the author gives details of a series of typical installations, with explanatory diagrams. Information is also given about combined hot water and central heating systems, and on the use of alternative systems for summer working. See Calorifier ; Heating : (6) ; *and* Hot Water Supply : (1).

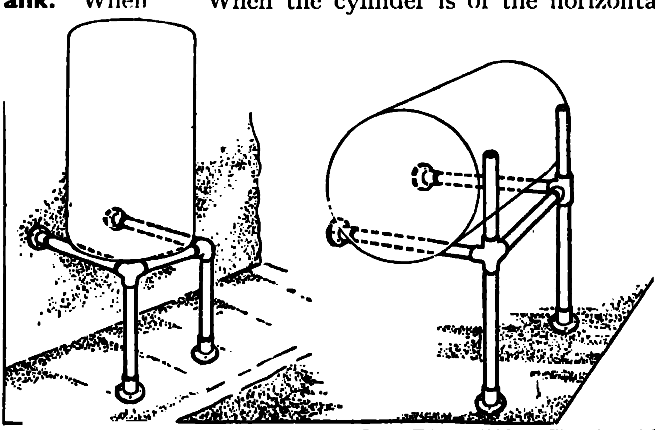
A folding Plate is inserted between pages 560-561: Figs. 4-7 and 10-11 are on the front; Figs. 12-15 are on the reverse side.

The layout and installation of a hot water supply apparatus involves several important considerations. Each separate constituent item must be suitable for its duty and position. The various parts must be properly interconnected, and the apparatus must be appropriate to the building in which it is installed.

The choice of a suitable boiler and its installation is considered under the heading Boiler: (2). Detailed information on boilers for combined heating and hot water supply systems is given under Heating: (6), a few notes on alternative systems being printed in the present article. Cylinders and tanks are dealt with under their appropriate headings. The general principles of hot water supply are explained under Hot Water Supply: (1).

Storage Cylinder or Tank. When a storage cylinder or tank is to be fixed on the same floor as a boiler, the cylinder must be at a higher level in order to obtain a gravity circulation. This will usually necessitate a special stand. The type of stand will depend on the cylinder—whether it is vertical or horizontal—and its position. Where the installation is to be made in a boiler-house and the cylinder is vertical, a brick or concrete base of suitable height will be best. It may be either round or square, and should be at least 6 in. larger in diameter or width than the diameter of the cylinder. If the cylinder is to be fixed in a kitchen a brick base will probably not be allowable. Here a stand made from pipe (like Fig. 1) will look neatest. The horizontal bearers are shown built into the wall ; but if this is of wood, the pipe may be screwed into the flanges, which in turn are fixed to the wood with screws, similarly to the floor flanges. Side outlet elbows are used to enable a front cross-piece to be fixed to keep the whole stand rigid. For cylinders up to 150 gal. capacity, 2-in. steam pipe will be strong enough. A similar stand can be made of angle iron, but the pipe stand has the advantage that it can be made up with the ordinary pipe-fitting tools on the job.

When the cylinder is of the horizontal

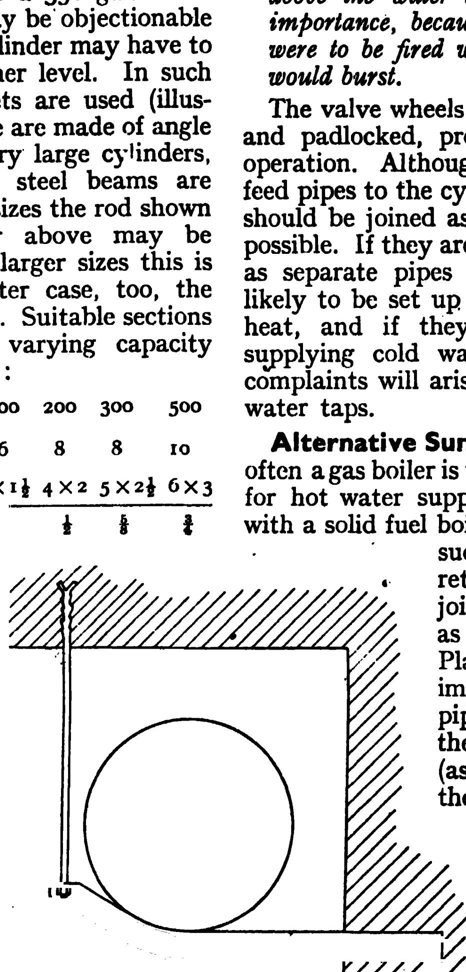


HOT WATER SUPPLY: LAYOUT AND INSTALLATION. Figs. 1 and 2. Pipe supports for cylinders : (left), for vertical and (right), for horizontal cylinder. Such stands can be made up with ordinary tools on the job.

type, the best type of support will depend on the cylinder capacity and its position. If it is to be fixed not more than about 4 ft. above the floor, a pipe stand similar to Fig. 2 is again very suitable. This is made up in the same way as Fig. 1, but the vertical legs are extended upwards to prevent the cylinder rolling when it is disconnected. Here 2-in. steam pipe may be used for a 150-gal. cylinder, 2½ in. for a 250 gal., and 3 in. for a 350 gal. The legs of such a stand may be objectionable in some cases, or the cylinder may have to be supported at a higher level. In such cases cantilever brackets are used (illustrated in Fig. 3). These are made of angle or tee iron; or, for very large cylinders, channel or H section steel beams are better. In the smaller sizes the rod shown fastened to the floor above may be omitted, but with the larger sizes this is essential. In this latter case, too, the brackets need not curve. Suitable sections for the brackets for varying capacity cylinders are as follows:

Cylinder capacity gal.	100	200	300	500
Depth to build bracket in wall, inches	6	8	8	10
Channel iron section	3×1½	4×2	5×2½	6×3
Diameter of rod		½	⅝	¾

The arrangements shown in Figs. 1, 2 or 3 may be used for supporting tanks. Horizontal cylinders may also be carried on brick or concrete piers not less than 9 in. wide and preferably shaped to fit the cylinder radius.



HOT WATER SUPPLY: LAYOUT AND INSTALLATION. Fig. 3. Angle iron or tee iron cantilever bracket for cylinder where pipework stand is unsuitable. *(Figs. 5-7 are on Plate f. p. 560).*

Duplicate Boilers and Cylinders. On any but the smallest installations it is good practice to fix boilers and cylinders in duplicate, each boiler and cylinder being one-half to two-thirds of the maximum duty required. In most districts, boilers and cylinders must be cleared of incrustation at least once a year. If a single unit is used, complete disorganization of the hot water supply service must occur when it is being scaled. A typical duplicate installation is shown in Fig. 4 on Plate *f. page* 560. Each boiler flow and return connexion is valved, and all connexions to the cylinders are fitted with valves. By closing the appropriate valves either boiler or cylinder may be completely isolated and worked on without interfering with the remaining part of the apparatus.

Note that each boiler is fitted with an open air pipe, which should be extended above the water level. This is of vital importance, because if one of the boilers were to be fired with its valves closed it would burst.

The valve wheels should also be chained and padlocked, preventing unauthorized operation. Although separate cold water feed pipes to the cylinder are shown, these should be joined as near the cylinders as possible. If they are taken up the building as separate pipes a circulation is quite likely to be set up in them. This wastes heat, and if they connect to a tank supplying cold water to other fittings, complaints will arise of hot water in cold water taps.

Alternative Summer Systems. Very often a gas boiler is used as a heating source for hot water supply service in summer, with a solid fuel boiler for the winter. In such cases the flow and return pipes should be joined as high as possible, as indicated in Fig. 5 (*see* Plate *f. page* 560). It is important that the return pipe should never connect the boilers horizontally (as shown dotted) or there will be a heavy waste of gas, since a circulation will take place through the solid fuel boiler when it is not being used. A valve may also be fitted on either flow or return, but it is better to avoid valves altogether in private houses.

Fig. 5 shows a direct hot water supply system. Often an indirect cylinder is used with a heating boiler for winter hot water supply when the heating load is much the larger of the two. The heating boiler cannot be used for direct hot water

supply, as there is no means of access to its waterways. During the summer when no heating is required it would be impossible to regulate the boiler to a sufficiently slow rate of combustion to deal with the hot water supply only. Such cases are best met by the arrangement shown in Fig. 6 (*see* Plate *f.p.* 560).

An indirect cylinder (*see* Heating: (6) has its internal heater connected to the heating boiler. The summer boiler (an ordinary hot water supply boiler, either gas or solid fuel fired) is connected to the body of the cylinder. The details of the hot water supply part of the apparatus are similar to any other installation. The flow from the heating boiler to the heater in the cylinder is best taken from one of the heating mains as shown. This automatically frees the heater of air. If an independent flow pipe from the boiler is used, it must have an individual vent.

Indirect cylinders are those containing a heating battery through which hot water or steam circulates to heat the water in the cylinder. The term calorifier (*which see*) is usually employed instead of indirect cylinder when steam is the heating medium.

Isolating the Heating System. In a private house it is often found that the water supply load is not smaller than the heating load. In such cases the arrangement of Fig. 6 may be used without the hot water supply boiler. A valve should be fitted on the main heating return pipe. When heat is not required this valve may be closed and will completely stop all circulation through the heating system.

A. INDIRECT CYLINDER SYSTEMS

When the water supply is very hard, a direct hot water supply boiler must be cleaned out at frequent intervals. To avoid this an indirect cylinder may be used. In this case the boiler should be of the heating type, since these are usually more efficient. It is necessary to use a separate expansion tank for the boiler side of the system, as shown in Fig. 7 (*see* Plate *f.p.* 560). On no account must the normal cold water supply tank be used also as the expansion tank, since the water supply will then be common to both sides of the system. The result would be a burnt-out boiler, owing to deposit forming in it. For such an apparatus the cylinder may be of galvanized steel.

Copper Cylinders for Soft Water. Very soft waters (some moorland and artesian or deep well waters) have corrosive actions on iron and steel. This necessitates the whole of the apparatus, including the boiler, being in copper. Copper boilers are obtainable in varying sizes and though it has been stated that they are liable to be attacked by sulphurous deposits of combustion, there is little or no evidence for it. A copper indirect cylinder with c.i. boiler will avoid corrosive action of water or combustion products.

Heating Surface in Indirect Cylinder. The area of heating surface necessary in the heating element of an indirect cylinder will depend on the rate at which the water is to be heated, the temperature rise required and the temperature of the heating medium. These factors may be combined into the formula:

$$\text{H.S.} = \frac{20G\,(t^h - t^c)}{K\,(t^b + t^r)}$$

where G is the quantity of water in gallons to be heated per hour.

t^h is the temperature required for the hot water, usually 150° F.

t^c is the cold water temperature, usually 40°–50° F.

t^b is the boiler flow temperature, usually 180° F.

t^r is the boiler return temperature, usually 140° F.

U is the heat emission in B.Th.U. per sq. ft. per hour per degree of difference.

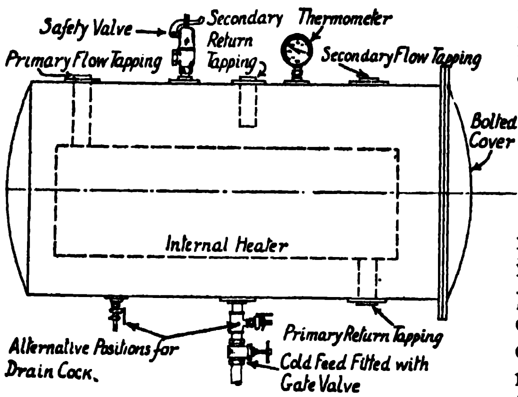
H.S. is the heating surface required in sq. ft. K may be taken as 60 for annular heaters, 40 for radiators and 70 for pipe coils, when hot water is the heating medium, and double these figures when steam used.

As an example, a 100 gal. indirect cylinder with radiator heating battery is to have its contents heated from 50° to 150° F. per hour; hot water having a flow temperature of 180° F. and a return temperature of 140° F. is flowing through the heater. What is the heating surface necessary in the heating battery?

Substituting figures in the formula, it becomes:

$$\text{H.S.} = \frac{20 \times 100\,(150-50)}{40\,(180+140)} = \frac{200{,}000}{12{,}800} = 15{\cdot}6\ \text{sq. ft.}$$

The figure thus reached is for clean heating surface. In hard water districts a certain amount of scale will be deposited on the heating element. To allow for this, 20 per cent. to 25 per cent. should be added to the calculated heating surface. If the example above were in a hard water



HOT WATER SUPPLY: LAYOUT AND INSTALLATION. Fig. 8. Indirect cylinder, showing fittings. (Figs. 4–7 are on Plate f.p. 560.)

district, therefore, the heating battery should be given a heating surface of about 20 sq. ft. instead of 15·6 calculated.

Draw-off and Safety Valve to Indirect Cylinder. An ordinary cylinder or tank may be emptied through the drain cock on the boiler. This is not the case with an indirect cylinder, and a separate draw-off cock should be provided either on the body of the cylinder or on the cold feed pipe between the valve and cylinder. A thermometer is desirable, since the boiler thermometer may not give the cylinder temperature. A safety valve fitted to the body of the cylinder is also valuable. The boiler safety valve is no protection if a fire is started with the cold feed valve shut, since water in boiler and cylinder are not common (Fig. 8.)

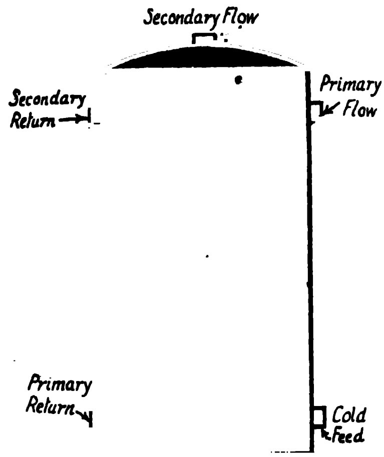


Fig. 9a. Desirable positions for tappings on vertical cylinder (see text).

Consult B.S. 1565 for galvanized indirect cylinders and B.S. 1566 (both 1949), annular types (water-to-water).

B. DIRECT CYLINDERS

Tappings on Direct Cylinder. The positions of the primary flow and return tappings on a direct cylinder should fulfil three requirements. They should be such that hot water is available soon after the lighting of the fire; the whole of the water in cylinder should take part in the circulation through the boiler; and they should allow the connexions to be made without any possibility of air locks.

Fig. 9a shows positions for tappings fulfilling these requirements. The flow connexion is at the top, meeting the first and third requirements; and the return is at the bottom to comply with the second condition. The position of the flow tapping in Fig. 9*b* is liable to the difficulty that the connecting socket will not be welded to the cylinder parallel to its horizontal axis. To overcome this the primary and secondary flow may be taken out of a common tapping on top of the cylinder. All the requirements are then met, provided the secondary flow rises from the cylinder to relieve air.

Also indicated on Figs. 9*a* and *b* are desirable positions for the remaining tappings necessary on a cylinder. The secondary flow is taken from the top to relieve air and to deliver the hottest water. The secondary return is taken from a point about 6 in. lower than the flow in Fig. 9*a*. It should never be lower than this, to avoid cold water flowing along the return pipe when a tap is opened. In Figs. 9*b* and 9*c* the secondary return joins the top of the cylinder. A dip pipe about 6 in. deep should be provided, as shown dotted, to ensure that circulation takes place in the desired direction. The cold feed pipe must join the cylinder as near the bottom as possible. Any storage below this pipe is wasted, since it is only water pushed out of the secondary pipes by the incoming cold water which is available at the taps.

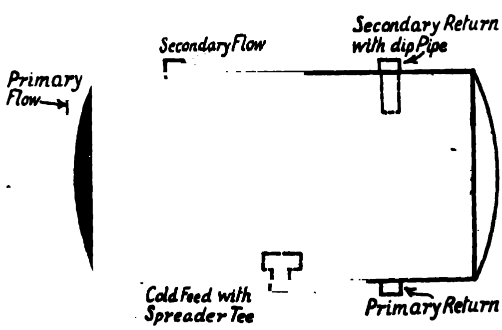
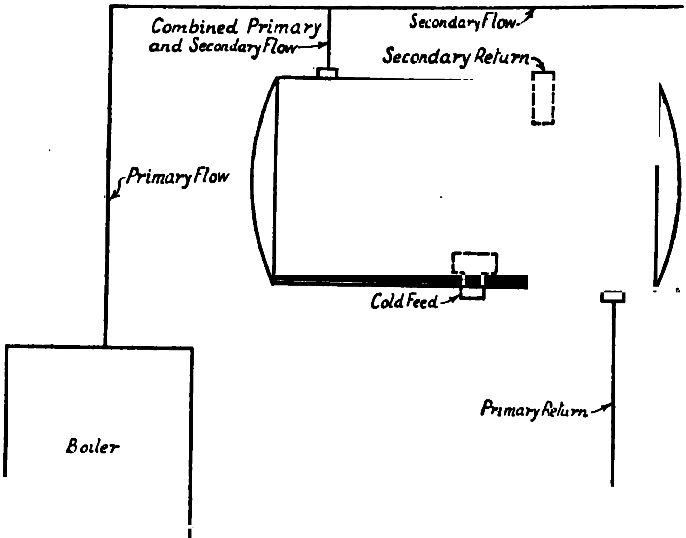


Fig. 9b. Desirable positions for tappings on horizontal cylinder (see text).



HOT WATER SUPPLY: LAYOUT AND INSTALLATION. Fig. 9c. Avoiding separate primary flow; combined primary and secondary flow and secondary return join top of cylinder.

(For Figs. 10–15 see Plate f.p. 560–561.)

The cold water should not enter the cylinder in a vertical direction, because a stream of it is likely to bore its way through the hot water to the secondary outlets. Fig. 9*a* complies with this condition, but with the connexions of Figs. 9*b* and 9*c* a spreader tee should be used as shown dotted. This tee may be fixed inside the cylinder by means of a nipple screwed into it and then one or two threads into the socket connexion. The joints for this tee need only be dry. Although cylinders have been used to illustrate the proper positions for connexions, the same principles apply when a tank is used as the storage vessel.

Limiting the Cylinder Circulation. It was mentioned above that the whole of the water in a cylinder should take part in the circulation through the boiler. Often when gas is the fuel it is desired for the sake of economy that only part of the cylinder contents should be heated when no large demand for hot water is likely.

This may be effected by having two return connexions as shown in Fig. 10, *See* Plate *f.p.* 561. The lower connexion is fitted with a valve, and on closing this the circulation takes place through the upper connexion, with the result that only the water above this becomes hot. When gas is the fuel, a valve is often fitted to the secondary return pipe. This may be shut at night, so preventing any considerable waste of fuel although the boiler be left alight to keep the cylinder full of hot water.

Pipe Sizing. The accurate calculation of pipe sizes for hot water supply service is dealt with elsewhere (*see* Pipe Sizing). The primary flow and return connexions between boiler and cylinder are usually so straightforward that calculation is unnecessary. The following sizes may be used where boiler and cylinder are not more than about 10 ft. apart, and cylinder is not less than about 3 ft. above boiler:

Up to	Cylinder	Up to	Cylinder
30 gal.	.. ¾ in.	120 gal.	.. 2 in.
45 gal.	.. 1 in.	200 gal.	.. 2½ in.
65 gal.	.. 1¼ in.	300 gal.	.. 3 in.

When the cylinder is of the indirect type the pipes should be one size larger.

C. TYPICAL INSTALLATIONS DESCRIBED

When hot water supply service is to be installed in a private house, the fuel question must be settled first. Probably the most convenient and economical installation is a small coke-fired boiler for normal use with an immersion heater for occasions when the boiler is out of use, as is often the case during the summer. The boiler will naturally go in the kitchen where a flue is available. The storage vessel may also be [illegible]d in the kitchen, particularly if a recess or cupboard is available. In this case a cylinder must be used. Usually, however, the appearance of the cylinder in the kitchen will be objectionable.

Probably the linen cupboard will be on the first floor, not too far from the kitchen. In this case, a 25-gal. tank in the linen cupboard will best suit the installation, assuming that a bath, basin and sink are to be supplied. The boiler should have a capacity of about 20,000 B.Th.U. per hour, equal to raising the temperature of 20 gal. of water 100° F. The immersion heater should be fixed near the bottom of the tank; full details of this will be found under the heading Immersion Heater.

Small House. The general arrangement of the apparatus is similar to Fig. 11 (*See* Plate). Normally a ¾-in. pipe will be sufficient to supply the fittings, although 1 in. will prevent any possibility of the

flow from one tap affecting that from another. In no case should the cold feed pipe be smaller than the secondary flow. The tee " A " should be kept as close as possible to the top of the cylinder, and it is preferable that the vent pipe be reduced in size above the tee. The whole object of these precautions is to prevent a mixture of air and water being discharged at the taps, an event particularly likely where the tank is not much above the cylinder.

If a towel rail is required the best method of connecting it under normal circumstances is to the primary flow and return, as shown in Fig. 11 (*see* Plate *f.p.* 561). The connexions can be ¾ in. diameter. When the rail is fixed on the wall it is possible to connect it to the secondary flow and take a secondary return back to the cylinder. When it is fixed on the floor this should not be done, since the return will have to join the cylinder at low level, and there is a possibility of cold water being drawn through it.

Combined Installations. The plans of a larger house are given in Fig. 12 (*see* Plate *f.p.* 561). It presents features which prevent a completely straightforward design being adopted, and so is doubly valuable as an example of hot water supply layout and installation.

The system is a combined one, the same boiler serving for heating and hot water supply. It was necessary to fix the storage cylinder in the linen cupboard, since the architect thought it would be unsightly in the kitchen. A vertical type indirect cylinder was adopted, the heater in it being connected to the boiler in the kitchen. The primary flow and return were run under the floor of Bedrooms 4 and 5. Notice particularly that the pipes turn into Bedroom 4 to run towards the centre of the house. They then turn into Bedroom 5 to reach the linen cupboard. This run was adopted so that the pipes run between joists all the way. If they had been kept in Bedroom 5 it would have meant notching the joists, for two fairly large pipes, during the first part of the run. The flow and return rise all the way to the cylinder, and a vent pipe on the flow keeps them both free of air.

A towel rail was fixed in the bathroom adjoining the linen cupboard. Since this was on the same level as the cylinder and a check valve was fixed in the secondary return, the circulation to this towel rail would have been very sluggish if it were connected to the secondary circulation. It was therefore taken off the primary flow and return as shown. The supply to the taps in this bathroom and the sink in the scullery were taken off the top of the cylinder and by the shortest possible route. No circulation is necessary, because of the short run.

The next item in the layout is the supply to the second bathroom, which again includes a towel rail. The same difficulty arises of cylinder and towel rail being on the same level. In this case, however, there is a sufficiently long run of flow pipe overhead to create a circulation. The return must be run back under the floor and connected to the bottom of the cylinder. To prevent cold water flowing back through this pipe to the taps, a non-return valve is fitted close to the cylinder. This valve must be of the special type having a very light clack which normally hangs partially open. An ordinary check valve in which the clack remains shut until pushed open would completely stop the circulation. The supply to the taps in the bathroom is taken from the flow to the towel rail.

A small storage tank is connected to the flow pipe in the roof. When a long secondary flow pipe has to be fixed but very little below the level of the water in the cold supply tank, there is a possibility of air being drawn through the vent pipe, causing an irregular discharge at the taps. This may be prevented by a subsidiary storage tank which will always keep the main full, as in the present instance. Another method is to make the overhead pipe at least one size larger than the drop pipe to the fittings. In this case the cold water feed pipe must be amply large enough.

Two further points in connexion with this installation may be noted. The main return from the radiators was fitted with a valve adjacent to the boiler. This enables the heating circulation to be stopped during the summer while leaving the boiler open to the expansion tank through the flow pipe. All pipes in the roof space and under floors were wrapped with asbestos felt insulation. This insulation adds to the necessity of running with the joists so far as possible, since an insulated pipe crossing a joist needs a

notch of depth equal to the diameter of the pipes plus the thickness of the insulation. Pipes crossing joists should not be allowed to rest in the notches, making contact with the wood, nor should they touch the underside of floorboards. The movement which takes place with expansion and contraction is likely to cause intermittent noises where such contacts occur. These noises may be difficult to trace. The complete arrangement of the apparatus is shown in Fig. 13 (*see* Plate *f.p.* 561), which is a pictorial view of the piping.

Layout for a Bungalow. The layout of the hot water supply installation for a bungalow, particularly where hot towel rails are required, presents difficulties. The cylinder must be fixed above the boiler in order to obtain a circulation through it. This will usually render impossible the fitting of it in a linen cupboard, and the only suitable place will be in the kitchen. A pipe may be taken from the top of the cylinder and run in the roof space to supply the taps. If these latter are remote from the cylinder a circulation will be needed, in which case both flow and return pipes should be run in the roof with drop pipes to the taps The circulation should be insulated. These pipes should be kept as low as possible in the roof, and they should be fitted with vent pipes. When determining their diameter remember that the head available is only that between the water level in the cold water tank and the pipe in the roof. It is not that between the tap and the tank water level.

The treatment of the towel rail circulation depends on the type of system adopted. If a combined installation is used with the same boiler for heating and hot water supply, an entirely individual circulation must run to the towel rail from and to the boiler. A typical installation of this type is given in Fig. 14 (*see* Plate *f.p.* 561).

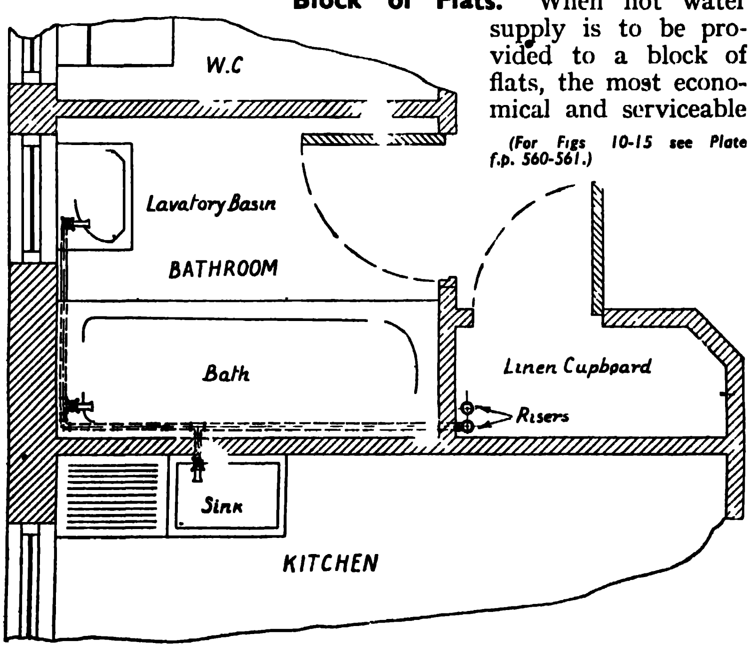
If an immersion heater is installed in the cylinder for summer use, the towel rail will not be hot when the boiler is out of action. If it is essential to have a hot towel rail during the summer, the best course is to use a special type with an enlarged bottom rail fitted with a small immersion heater, which should incorporate a thermostat.

When the hot water supply is on the direct system the installation may be arranged as shown in Fig. 15, *in* Plate *f.p.* 561. The taps are supplied from the flow pipe to the towel rail, the pipe being fixed in the roof.

The return pipe from the towel rail is run under the floor and connected independently to the boiler. On no account should the towel rail return be connected to the primary return. The water temperature in the latter will vary widely, and when it is cool will tend to retard the circulation through the rail. A better but more expensive method of serving the towel rail is to give it an entirely separate flow and return direct from the boiler. The temperature of the water in the cylinder will then be completely without effect on the rail circulation.

Block of Flats. When hot water supply is to be provided to a block of flats, the most economical and serviceable

(For Figs 10-15 see Plate f.p. 560-561.)



HOT WATER SUPPLY: LAYOUT AND INSTALLATION. Fig. 16. Block of flats: pair of flow and return risers taken through linen cupboard in each flat, with under-floor branches to serve fittings.

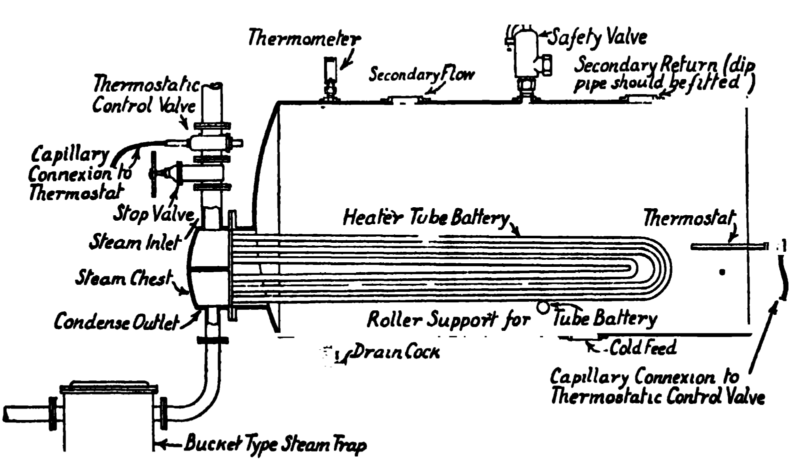
piping layout will usually be the two-pipe up-feed, assuming the boiler and cylinder can be below the lowest floor of flats. When this is not so, the down-feed system must be adopted. If each flat has a linen cupboard, a pair of flow and return risers may be run through it with under-floor branches to serve the fittings, as shown in Fig. 16. A pair of valves on the branches will enable each flat to be isolated. This arrangement will not be possible with solid floors where flats have more than one bathroom and these rooms are widely separated. Here it will be necessary to fix risers adjacent to each bathroom and, if necessary, the kitchen.

Except in the smallest block of flats it is best to use duplicate cylinders and boilers to ensure continuity of service. If this is not possible, on account of cost or other reason, then at least duplicate cylinders should be provided. When comparatively long runs of piping are involved, an accelerator will usually make the job a better one. These are dealt with under their own heading, but a few points peculiar to hot water supply service may be noted. The impellor and, if necessary, the body of the pump must be made of some material unaffected by the water used. This does not arise with heating systems, where the same water is used continuously. The pump must be connected to the secondary circulation and will have no effect on the primary circulation. Boiler and cylinder must be so placed, therefore, to allow a gravity circulation between them. If the pump is intended only to assist the circulation a very low head should be used. If it is used to assist the outflow from the taps also, the head may be as large as desired, but the pump must be capable of dealing with the maximum flow likely at this head when the greatest number of taps are in use. In this case the pump must be connected to the secondary flow pipe.

Factory Installation. The hot water supply installation for a factory will follow the same general lines as any other as regards piping, etc. The only matter peculiar to such a building is that steam is often available. In this case it is usually more economical, both in first and running costs, to install a calorifier (*which see*).

A steam heated storage calorifier is similar in general principle to an indirect cylinder, but usually has the heating battery in the form of copper pipe surface, as shown in Fig. 17. The steam connexion should be fitted with a thermostatic control valve to regulate the water temperature. It must be remembered that since steam is the heating medium it is quite possible to heat the water in the calorifier to a dangerous temperature and even to boil it. The thermostatic valve when properly set limits the temperature of the water. In addition, a steam stop valve should be fitted to the supply pipe.

The outlet from the battery is fitted with a steam trap which should be of the bucket type. It should have a capacity of not less than five times the normal condensing capacity of the coil. This allows for the rush of condense water when steam is first turned on to the cold calorifier. The body of the calorifier should be fitted with a safety valve, thermometer and draw-off cock. The calorifier is usually carried on cast iron or steel cradles. Sufficient space must be left in front of it to withdraw the battery for scale removal.



HOT WATER SUPPLY: LAYOUT AND INSTALLATION. Fig. 17. Steam-heated storage calorifier with heating battery of copper tube.

HOT WATER SUPPLY: (3) BY GAS-FIRED BOILERS AND CIRCULATORS

By J. Murray Grammer, Assoc.M.Inst.Gas E., A.M.I.H.V.E.

Boilers fired by gas are dealt with in the seventh of the Boiler group of articles, where particulars of types for hot water supply will be found. The present contribution is concerned with the installation of such appliances. The Sections are: A, Domestic Circulators; B, Installation; C, Gas Boiler as an Alternative Unit; D, Running Costs. For gas-fired instantaneous water heaters see the following article (No. 4) in the present Group. Thermal Storage Heaters are dealt with later in this work under that heading.

The term "boiler" used almost universally for domestic hot water appliances is incorrect: solid fuel appliances certainly do boil occasionally, owing to overstoking, lack of control, or partially blocked pipes; but in the case of gas-fired water heaters the implication is entirely misplaced. Of all the benefits claimed for gas-fired water heating appliances, perhaps the most important is the ease with which the maximum temperature, fuel consumption and heating power can be controlled. For a modern gas water-heater to "boil" would imply a serious breakdown in the design or application of the appliance.

There are certain gas appliances to deliver boiling water or steam, but these are limited to the restaurant boiling water machines (there are some domestic models), and mild steel or copper pressure boilers to supply steam for large catering work or process work. (Instantaneous heaters are dealt with in the next article in the present Group.)

A. DOMESTIC CIRCULATORS

The domestic boiler or gas circulator (this latter expression indicates its method of heating) consists of a comparatively simple body and waterways. The waterways are not subjected to pressures higher than those effected by the cold-feed tanks in the houses in which the circulators are fitted, as in every case the circulation system is vented to the free air by means of an expansion pipe. Thus, even if by a mischance steam were generated, there would be no additional internal pressure on the circulator. Maximum permissible heads on these heaters vary from between 100 ft. for some of the cast-iron circulators to 50 ft. on some of the copper and smaller types.

The circulator is connected in the piping circuit of a hot water installation and functions in the same way as a boiler fired by solid fuel, warming the water which circulates through it, the water being stored in a separate tank or cistern. The instantaneous water heater (dealt with in Hot Water Supply: (4)) warms water more rapidly, and the water is delivered direct to the taps, there being no storage vessel. Thermal storage heaters combine with the heating unit a storage space.

Trends of Modern Design. Originally all circulators were made with cast-iron waterways, which provide a general heat interchange over a fairly large superficial area and give consistently high water heating efficiencies (often above 75 per cent.). More recently, however, in an endeavour to widen the use of gas circulators some very much cheaper types embodying copper waterways have been manufactured, and with these almost the same efficiencies have been obtained.

Owing to simplicity in design and the very short length of waterway, coupled with the fact that nearly all the heat transfer takes place over a small area, there is a tendency to quicker scaling up at this local point. But investigation and experiment are extending the distance between the heat transfer limits, and indicating types of heat interchanger that will avoid overheating. Overheating at local points must be avoided with the copper types, otherwise the fins may become detached.

That it is worth while persevering with these cheaper and smaller circulators (so easy to install) is evidenced by the great numbers of them in use on the areas of certain gas undertakings today. Even if they may tend to scale up a little more quickly (and with careful installation and adjustment this can be minimized), the ease with which they can be dismantled and cleaned is a considerable advantage.

Gas Rate and Output. A circulator operates in connexion with the storage vessel of a tank or cylinder system—with gas it should always be a cylinder system—and thus the service from a given circulator depends on the size and shape of the storage and the size of the flow and return pipes. Unlike an instantaneous water heater or a thermal storage heater, full performance figures of which could easily be quoted, all that can be said of a circulator is that it has an output of so many gallons of water raised 90° F. per hour.

Installation performance figures for a complete circulation system can be given only when the size of the storage vessel is known, the storage temperature determined, and the rate of circulation decided which indicates the flow temperature. The main value of any circulator—but particularly of the gas one, which is so easy to set—is that it can be linked up with existing storage vessels and systems; or, as we shall see later, it can be installed as an alternative to an existing solid fuel boiler system. If one knows the storage capacity, the daily demand, and the times and size of maximum demands, a circulator of water heating output just necessary for the particular job can be chosen.

Although a circulator of any output can be manufactured, the domestic appliances are found to give the following range (gas of 500 C.V. is assumed throughout):

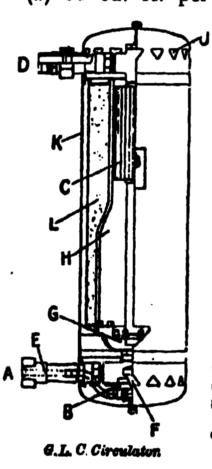
(*a*) 10 cu. ft. per hour maximum gas rate. Output 4·2 gallons of hot water per hour raised 90° F.

(*b*) 30 cu. ft. per hour maximum gas rate. Output 12·5 gallons per hour raised 90° F.

(*c*) 60 cu. ft. per hour maximum gas rate. Output 24 gallons per hour raised 90° F.

(*d*) 80 cu. ft. per hour maximum gas rate. Output 34 gallons per hour raised 90° F.

In selecting a circulator for a particular job, all that has to be done is to see that it is powerful enough to heat up a given bulk of water in a given time, and that if the whole of the stored hot bulk should be emptied down, the circulator is powerful enough to make up sufficient hot water in time for the next demand. Methods of estimating the hot water demand are given in Hot Water Supply: (1), and therefore that subject need not be dealt with here.



G.L.C. Circulators

HOT WATER SUPPLY: GAS CIRCULATORS. Fig. 1. 30 cu. ft. per hour circulator: A, return connexion; B, capsule thermostat; C, finned water tube; D, flow connexion; E, gas inlet; F, gas governor; G, burner; H, annular flue-way; J, flue outlets; K, outer casing; L, lagged inner case.

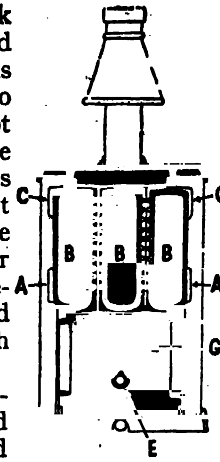


Fig. 2. 60 cu. ft. per hour boiler: A and A1, return connexions; B, interconnected water sections; C and C1, flow connexions; E, burner; G, brick-lined combustion chamber; P, gas supply pipe. *(Ideal Boilers & Radiators, Ltd.)*

For greatest efficiency, a self-contained plant (circulator and storage vessel under one lagged case, *see* Thermal Storage Heaters) should be used, the circulator and storage vessel as separate items being employed only where local circumstances justify it. These circumstances are, however, very common, and a good example is where there is space for a circulator in one room and space for the tank elsewhere, but no one room available having space for the complete plant.

Control and Adjustment. Gas circulators have three points of control or adjustment;

Gas Rate Control. First, there is the gas rate control, which generally consists of a throttle or sleeve in the gas way to a luminous burner (luminous burners are used because of their stability at maximum and by-pass gas rates). This throttle should be adjusted, after fixing or after a maintenance call, to show the correct working pressure at the pressure-test point. The gas rate should then be checked finally by timing a complete revolution of the test-dial of the meter.

Thermostatic Control. The second control is the thermostatic one, which is generally fitted to the base or "return" part of the circulator, although it may be embodied in an extended and integral return pipe. Since luminous burners are used, there is no need for snap-action thermostats, as there is no fear of "lighting back" when the burner is turned down slowly.

Most thermostats on circulators are adjustable, as the temperatures for storing

hot water vary in different parts of the country, and higher temperatures are demanded for certain purposes by some users. In London the gas companies generally consider a return temperature of 140° F. as being high enough for domestic purposes, and at the same time sufficiently low to avoid heavy scale formation inside the circulator, with its burden of expensive maintenance service.

Nevertheless, in certain jobs where the storage vessel is on the small side, or where it has become imperative to keep one tap —perhaps the kitchen tap—served from a connexion to the flow pipe, it is permissible to step-up the temperature to increase the heat storage or to overcome partially the effect of cold water mixing with the hot on its way to the draw-off.

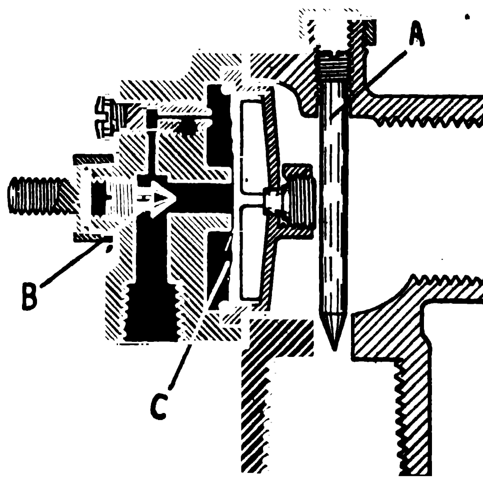
The smaller circulators are exceptions in that their thermostats are generally not adjustable. One kind has a bi-metal rod type, sealed and non-adjustable; while others have non-adjustable expanding capsules in the return connexions. Some of the capsules contain wax; others contain volatile liquids.

Of the larger circulators, one type has a vertical bi-metal rod thermostat fitted into a vertical return connexion, the gas valve with adjustable screw-head being at the bottom. Another type employs an expanding bi-metallic strip which can be adjusted by a screw at its centre.

A further type advertised extensively as a substitute heater for a coke boiler (and this job it will undertake very well) employs the adjustable relay type of thermostat. In this last case the thermostat detector head is inserted in an alternative return tapping in the sectional boiler casting; the effect of its opening or closing at the prescribed temperature is communicated to a relay valve on the gas supply to the circulator or boiler by means of a small copper weep pipe. This method has the advantage of a nearer approach to "snap" action which, although technically not necessary, gives visible evidence of control to the user.

The practical advantage of this thermostat is the improvement it facilitates in installation. Instead of having a bulky control on the exterior of the heater, a small detector can be used, and the bulkier gas valve can be hidden out of the way (*see* Thermostats).

Restrictor Control. The third control on a circulator is the restrictor control. This is very important with all circulators but especially so with the smaller types. A restrictor fitted on the return connexion to a circulator enables the rate of flow of water through the appliance to be adjusted. Without the adjustment of a restrictor, the water flow rate, and hence the flow temperature,



HOT WATER SUPPLY: GAS CIRCULATORS. Fig. 3. Section of controls of a 30 cu. ft. per hour circulator: A, screw throttle type of water restrictor; B, gas throttle; C, wax capsule thermostat.

in a system would depend entirely upon the available "circulating head." In a hot water system this head depends mostly on the height of the storage vessel above the boiler which can vary from a few feet in a small house to a considerable vertical distance in a larger one. (N.B.—Flow and return pipes should be kept as short as possible when using gas as a fuel, since unnecessary heat losses must be avoided.)

According to the available "circulating head," therefore, the restrictor has to be set to give the required water flow rate and hence flow temperature. With a quick-heating circulator the flow temperature control is not too important (so long as it is not too high), as the whole bulk of hot water can soon be circulated round and a full storage provided ready for use after so short a period as an hour. With a small circulator, however, a good hot water service may depend entirely upon the fact that the "stratification effect" in a good cylinder system is being employed to provide small quantities of hot water ready for use soon after lighting up. This

can be arranged only by so setting the restrictor that the flow temperature is that at which water is required to be used, so that it can be circulated to the top of the storage vessel and held there, a slowly growing accumulation of hot water usable to the limit of its volume, in spite of all the cold water beneath it.

Restrictors may be of the following types:

(1) An adjustable needle or screw throttle; this type is sometimes troubled by scale formation.

(2) A restrictor plate in the return connexion, with removable variable orifices; these latter are sometimes marked (*e.g.* a certain numbered orifice for a certain height between the circulator and the storage tank).

(3) Restrictor tees similar to those used in balancing sections of central heating circuits.

(4) Valves that can be locked are sometimes inserted on the return pipe, but this seems an expensive method.

(5) Actual reduction in pipe sizes on the flow and return connexions—really the best way, and following on the lines of pipe sizing for central heating installations.

With combined circulation sets no restrictor control is necessary, as the circulating head is a constant for all the sets of the same design.

B. INSTALLATION OF CIRCULATORS

There are many houses provided with a solid fuel hot water supply installation which is quite adequate but involves a lot of personal attention and may be an embarrassment in summer. Here should be recommended a 60 cu. ft. per hour or a 80 cu. ft. per hour circulator; for smaller jobs or more limited requirements (and above all where no flue can be fitted), a 30 cu. ft. per hour or even smaller circulator may be selected. This, of course, is connected in place of or as an alternative to the existing boiler. Taking advantage of the two-part tariff rates offered by some gas companies, an efficient and lagged gas installation works out as cheaply as coke in the average suburban household.

The actual fitting of circulators should be extremely simple. In an entirely new job, so long as there are provided a cylinder system with short flow and returns, clean connexions to the tank, spreader tee or its equivalent on the entrance of the cold feed to the tank, and adequate lagging, there is no need for special precaution.

Many of the installations, however, are under replacement or alternative schemes, and care must be taken in these: it is often the case that defects overcome by forcing a solid fuel boiler become only too apparent when the more closely controlled gas appliance is fitted to the system.

Replacement Jobs. A general rule in replacement jobs is never to fit a gas circulator to a tank system, unless there are very exceptional circumstances (such as the odd draw-off tap that cannot be transferred to the expansion pipe): if such a system is put in, the user should be warned of the possible trouble that may be experienced. In most cases, although the flow and return pipes cannot be shortened (in suburban houses these are often of necessity the same length for a cylinder system as for a tank system), the draw-offs can easily be transferred to a draw-off pipe coming from the expansion pipe. The tank system is considered inferior because of the likelihood of drawing hot and cold water together when a hot tap is operated. This may not be unduly serious if the tank is filled with water at, say, 200° F., as is possible from solid fuel heating; but with gas heating—which will be thermostatically controlled—the resulting temperature at the tap will be too low.

It must not be imagined that in these replacement jobs the fitting of a gas circulator to a bad solid fuel system will make it a good one.

The following points also should be noted as possible causes of poor results:

1. *Cold Feed Connexion.* This is often found connected without means of deflecting the flow of the incoming cold water, thus disturbing the stratification and chilling the stored hot water. To correct this, fit a spreader tee or its equivalent.

2. *Flow Pipe Connexion.* This is sometimes found to pass into the tank at the bottom and thence through the water to the top, which will cause an undesirable transference of heat from the water in the flow pipe to the cold water in the lower part of the tank. To correct this the original connexion should be cut out and a new one made to the expansion pipe, just above the top of the tank or to the top of the tank itself.

3. *Capacity of Existing Storage Vessel.* Occasionally the tank or cylinder is too large for the requirements of the job. (This may not have mattered much with cheap solid fuel.) The storage may be reduced by raising the return connexion to the storage vessel and/or by the use of a two-way (economy) valve. *See* Fig. 4.

The use of a two-way economy valve is also justified when it is known that a reduced service will be required at certain times.

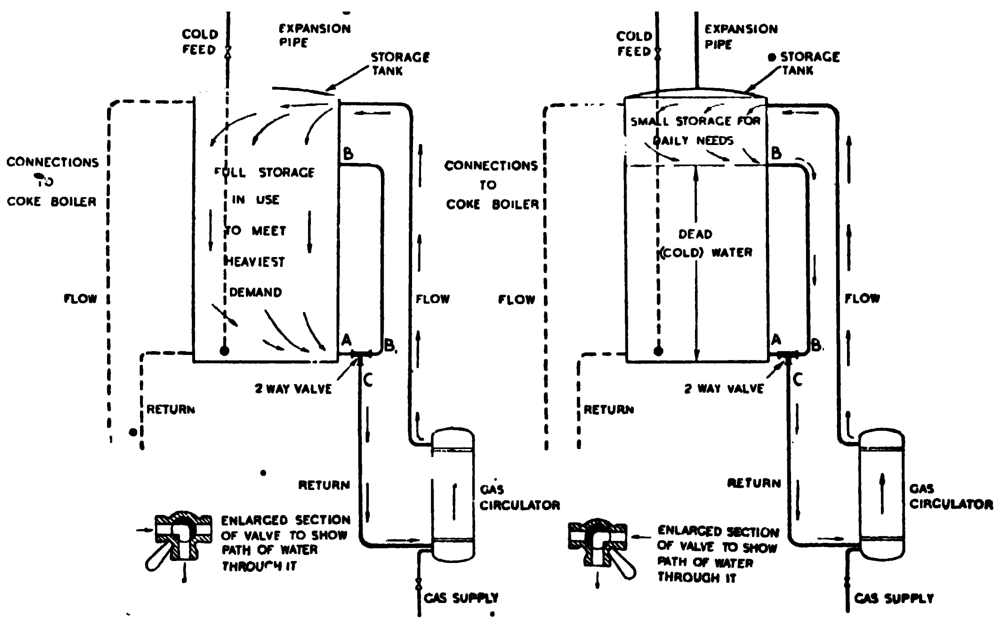
Further points that arise in replacement jobs concern the flue, furred pipes, radiators and towel rails. With regard to the flue work this must, of course, conform

to the "I.G.E. Regulations, 1937" and to any local regulations. Generally, a circulator, if it requires a flue at all, already has the primary flue and baffler as approved and integral parts of the appliance. All that has to be considered, then, is the secondary flue and the terminal. A standard run to the outside air is straightforward, but may be more expensive and certainly less neat than running the flue into the chimney previously serving the solid fuel boiler. So long as additional ventilation is given to such a chimney by an air brick, by removing the cleaning door or by a special annular opening with distance pieces to hold the flue, no condensation difficulties need be feared.

Furred pipes will not affect the increased efficiency of a new gas boiler or circulator. Moderate scale in the existing flow and return pipes can be ignored; and even if the flow pipe is badly furred up, replacing the first few feet will usually be sufficient to make things right. It is not to be considered necessary in every case to fit larger or different pipes; if the solid fuel boiler works well without the need for "forcing," then the gas boiler should work equally well and in many cases better.

With regard to radiators and towel rails, these will all work as well on a gas-fired system as on a solid fuel system, but the question of running costs should be borne in mind. Most radiators can be allowed for on a known B.Th.U. output; or as a rough figure the basis that one large radiator (10 loops) is equivalent to a gas rate of 8 cu. ft. per hour can be taken.

Battery of Boilers. In larger jobs (both new and replacement) it is sometimes found that rather than one large gas boiler it is more convenient to install two or three smaller ones as a battery, serving one common storage vessel. The convenience often lies in the better allocation of space, reduction of the size of the system during slack periods, ease of maintenance, etc. In arranging these batteries of boilers or circulators, probably the most important consideration is the flue. In the past a common sloping flue open at one end with connexions teeing down to the flue spigots of the appliances was considered the best practice; but to-day, especially with the advent of the integral baffler, it is considered better to have a separate baffler for each appliance and then to run a common secondary flue to the point of termination. The end of the common flue need no longer be left open, except perhaps to entrain some excess air to reduce the possibilities of condensation. As much vertical run as can conveniently be got is essential on this secondary flue.



HOT WATER SUPPLY: GAS CIRCULATORS. Fig. 4. Use of two-way valve to regulate amount of hot water stored in circulation system: (left diagram) storage tank in full use, valve being operated (see enlarged section) to allow water to flow in direction A—C, as shown by arrows; (right) hot water circulation restricted to small top storage space by opening valve (see section) to convey water through pipes B—C.

Fig. 5

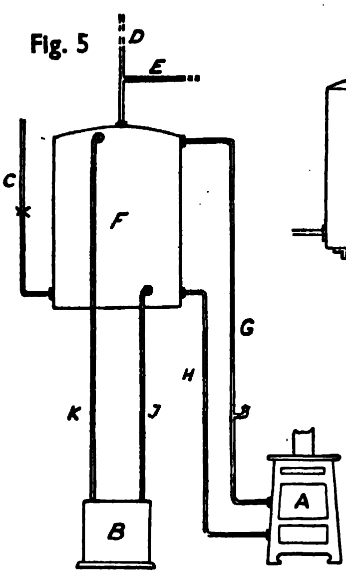


Fig. 6

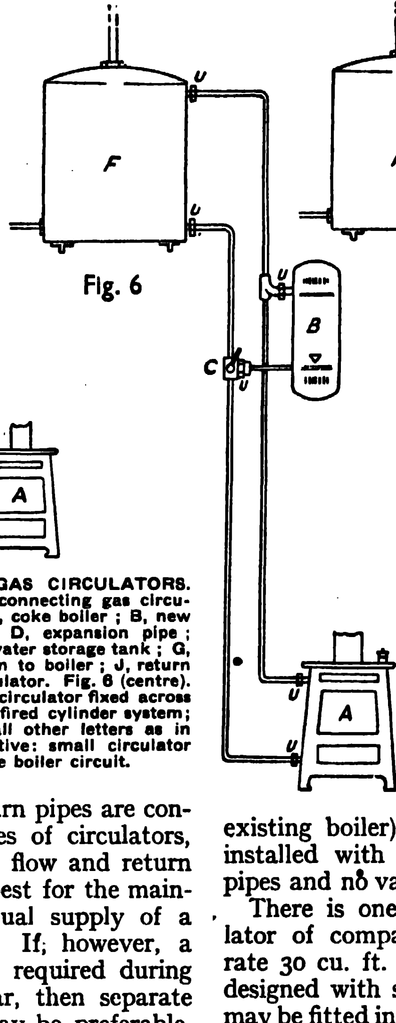
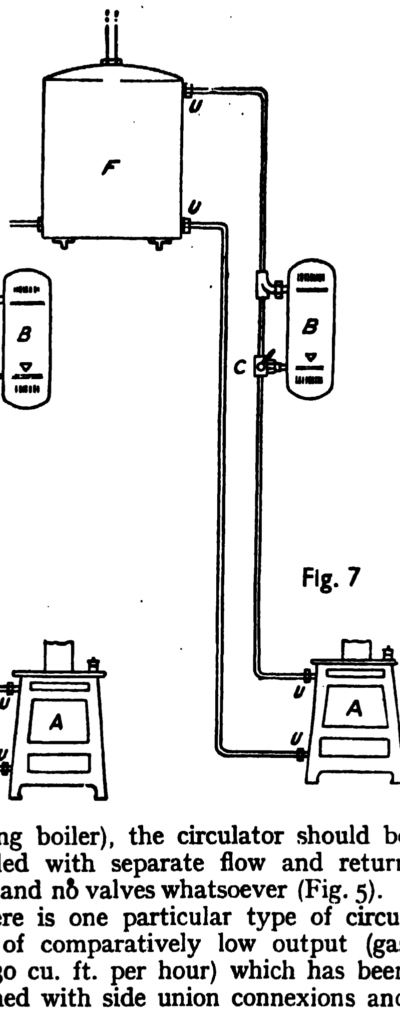


Fig. 7



HOT WATER SUPPLY: GAS CIRCULATORS. Fig. 5 (left). Best method of connecting gas circulator to existing installation : A, coke boiler ; B, new gas circulator ; C, cold feed ; D, expansion pipe ; E, supply to draw-off ; F, hot water storage tank ; G, flow from coke boiler ; H, return to boiler ; J, return to circulator ; K, flow from circulator. Fig. 6 (centre). First alternative method: small circulator fixed across flow and return pipes of coke fired cylinder system; C, special cock ; U, unions ; all other letters as in Fig. 5. Fig. 7. Second alternative: small circulator piped in series with coke boiler circuit.

As far as flow and return pipes are concerned on these batteries of circulators, common headers for the flow and return connexions prove to be best for the maintenance and the continual supply of a full bulk of hot water. If, however, a reduction of service is required during slack periods of the year, then separate flow and return pipes may be preferable.

In either case, although the introduction of valves on the flow and return pipes may seem a great benefit from the point of view of maintenance, unless they are under the supervision of a competent resident engineer they are merely a potential source of trouble in inexperienced hands. Valves are unnecessary on all but the very largest of domestic installations.

C. GAS BOILER AS ALTERNATIVE SYSTEM

This is a field where the gas boiler or circulator can be used to great advantage. Thus it makes possible a cool kitchen in summer by taking over the whole water heating load ; and can assist the solid fuel boiler in winter by running simultaneously with it. If it is to perform its job to the best advantage (especially if it is to run simultaneously as a "booster" for the existing boiler), the circulator should be installed with separate flow and return pipes and no valves whatsoever (Fig. 5).

There is one particular type of circulator of comparatively low output (gas rate 30 cu. ft. per hour) which has been designed with side union connexions and may be fitted in other ways for convenience and sake of appearance as follows :

(*a*) The best alternative to the use of separate flow and return pipes is to connect across the existing flow and return, so that the solid fuel boiler is by-passed and the circulator cannot be used at the same time as the solid fuel boiler. A valve operating both the waterways and the gas way should be fitted, to enable the user to make an easy change-over from one fuel to another. (*See* Fig. 6.) It will be noticed that in this instance the gas heater cannot augment or "boost" the solid fuel boiler.

(*b*) Coming after method (*a*) in order of merit, this system (*see* Fig. 7) is arranged so that in series with the existing flow pipe a valve similar to the one mentioned in method (*a*) must be fitted. The coke boiler then becomes part of the return pipe to the circulator, and is, of course, a potential source of heat loss. It is clear that for continuous operation the fixing of the circulator on the flow pipe should be only a last expedient ; and although the circulator could be used at the same time as the coke boiler, this would probably result in need for increased maintenance.

With all three methods the existing system must be a cylinder system or be convertible to a cylinder system.

Indirect Systems. These are common with solid fuel systems today, but very often when a central heating system shuts down in the summer, or even because of the nuisance of heat from the solid fuel boiler, some alternative method is desired, sized up for the summer domestic hot water load only.

The gas circulator here is brought in by direct separate flow and return connexions to the storage vessel—the calorifier or indirect heater remaining in position but out of use for the time being (Fig. 8). The illustration shows the simplicity of such an installation, which has no additional valves save, perhaps, a two-way economy valve for the reduction of storage. It would be wiser to shut down the central heating circuit (if any) while the gas circulator is in use.

D. RUNNING COSTS OF GAS-FIRED HOT WATER SYSTEMS

Although on the question of costs it has been stated that gas on a two-part tariff rate can be as cheap as solid fuel in a suburban home for water heating, the statement holds good only when the coke boiler is a normal unlagged installation and the gas boiler or circulator substitute forms part of a satisfactory lagged cylinder system. It is the lagging of the existing pipes and storage that makes it possible for gas to be used on a competitive basis.

But some users, in spite of increased running costs due to unlagged pipes and storage, will prefer the fuel for the sake of its convenience; and others like the additional warmth in the house. The amounts involved should be considered by the engineer so that the future user of the installation can be advised of the amount he is likely to save by paying out initially for the extra work of lagging.

Some examples of heat loss costs are:

(*a*) 1 in. pipe, bare or painted with non-metallic paint.

(1) Heat loss per hour for 10 ft. run (water at 140° F) = 660 B.Th.U.

(2) The same pipe when lagged (same conditions) loses only 135 B.Th.U. per hour.

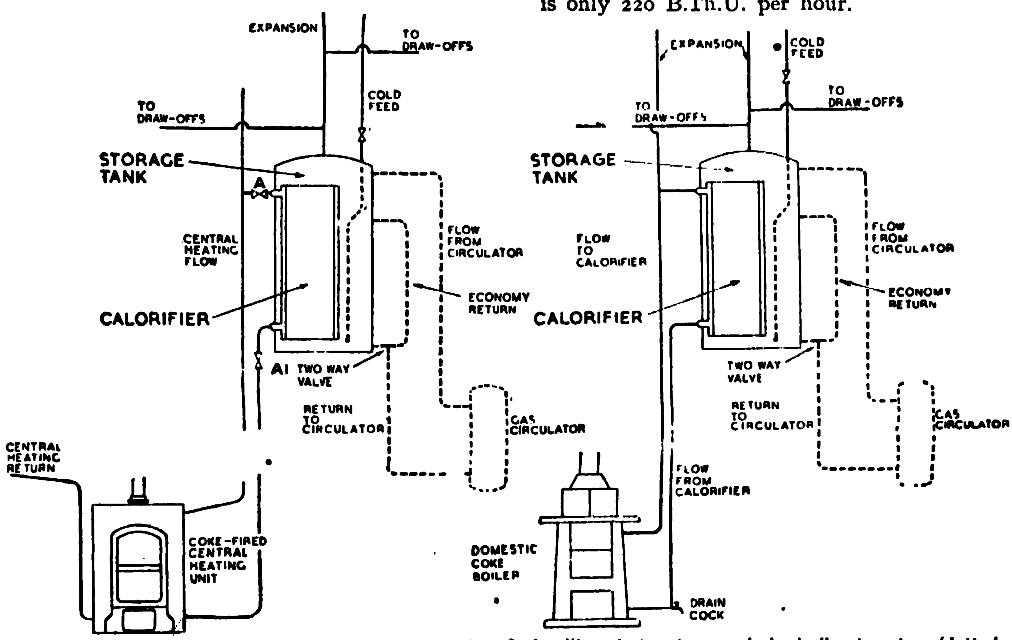
These losses translated into costs with gas at the alternative rates of 9d. per therm and 4d. per therm show that the equivalent weekly costs of gas (75 per cent. efficiency) per 10 ft. run are:

(1) For the unlagged pipe 13·3 pence at 9d. therm, 5·9 pence at 4d. therm.

(2) For the lagged pipe 2·8 pence at 9d. therm, 1·3 pence at 4d. therm.

(*b*) (1) 10 sq. ft. of galvanized-iron tank surface when unlagged loses 1,200 B.Th.U. per hour (water at 140° F.).

(2) When the same surface is lagged the loss is only 220 B.Th.U. per hour.



HOT WATER SUPPLY: GAS CIRCULATORS. Fig. 8. Auxiliary hot water supply by indirect system (dotted in) for use when central heating apparatus (left) or independent boiler (right) is not in use; gas circulator is connected by independent circulation to storage tank, and a two-way valve regulates quantity of hot water in use (compare Fig. 4); A and A1 are stopcocks to shut down circulation from central heating unit.

When translated into costs with gas at the alternative rates of 9d. per therm and 4d. per therm, the equivalent weekly costs of gas (75 per cent. efficiency) per 10 sq. ft. of galvanized tank surface are:

(1) For the unlagged tank 24·3d. at 9d. therm, 10·8d. at 4d. therm.

(2) For the lagged tank 4·5d. at 9d. therm, 2·0d. at 4d. therm.

As general rules for the installation of gas circulators we may say that all storage tanks should be lagged; and the supply pipe to any hot tap likely to be used on an average more frequently than once per hour must be lagged.

Maintenance. The maintenance of gas circulators does not differ greatly from that of other gas water heating appliances (*see* notes on instantaneous water heaters under Hot Water Supply: (4)), as the usual rules concerning the state of the flue pipe, baffler and terminal (if any) must hold good. Also (and this cannot be stressed too much) it is essential that the burners should be left in sound condition and the gas rate set and properly checked by a test with the meter and a watch.

Apart from these points and the usual cleaning of flueways, etc., the only major operation is the cleaning of the waterways. To do this properly the circulator should be entirely disconnected and the scale removed by de-scaling tools and chemical de-scaling fluids. It is in the disconnexion of the appliances that care must be taken: the fact that no valves are recommended on the flow and returns means that the whole system must be emptied down before the circulator is removed. This should be done preferably through the emptying cock, which to-day often forms an integral part of the appliance. A stopcock on the cold down-feed to the system is a great advantage to the maintenance man; to-day this cock is hardly ever omitted.

When assembling the circulator, use new jointing washers to replace old ones; tighten any plugs previously loosened, and then let the water in and test for soundness. All draw-off taps should be opened before letting the water in, and should be left open until the water flows freely through each. This should help to prevent air locks.

HOT WATER SUPPLY: (4) INSTANTANEOUS GAS WATER HEATERS

By J. Murray Grammer, Assoc.M.Inst.GasE., A.M.I.H.V.E.

In this contribution Mr. Murray Grammer reviews the leading types of instantaneous water heater burning gas fuel, with notes on the choice of appliances for specific duties. Fixing instructions are given, with diagrams. The arrangement of Sections is: A, Types of heater; B Choice and running costs; C, Valves on heaters; D, Fixing; E, Ventilation of heaters; F, Instantaneous heater as alternative system; G, Maintenance.

Instantaneous water heaters (known in their earlier days as geysers) are probably the most numerous of domestic gas water heating appliances. This does not mean that there is an instantaneous water heater for every possible type of job, but rather implies that they can be used in most cases with varying degrees of success.

No hot water engineer, plumber or builder should limit his recommendations to one particular type of water heating appliance, but should review each case on its merits, remembering that the ideal is "hot water at any time and at any tap." The perfect installation often costs too much initially, and provides a better service than that for which the user can afford to pay; hence it is that the humbler systems are more often the order of the day. Rather than aiming always at a "second best" system, however, the engineer should go out first of all for the "full bore" service; but until the public becomes more appreciative of, and able to pay for, such a service, these other installations will continue.

A. TYPES OF HEATER REVIEWED

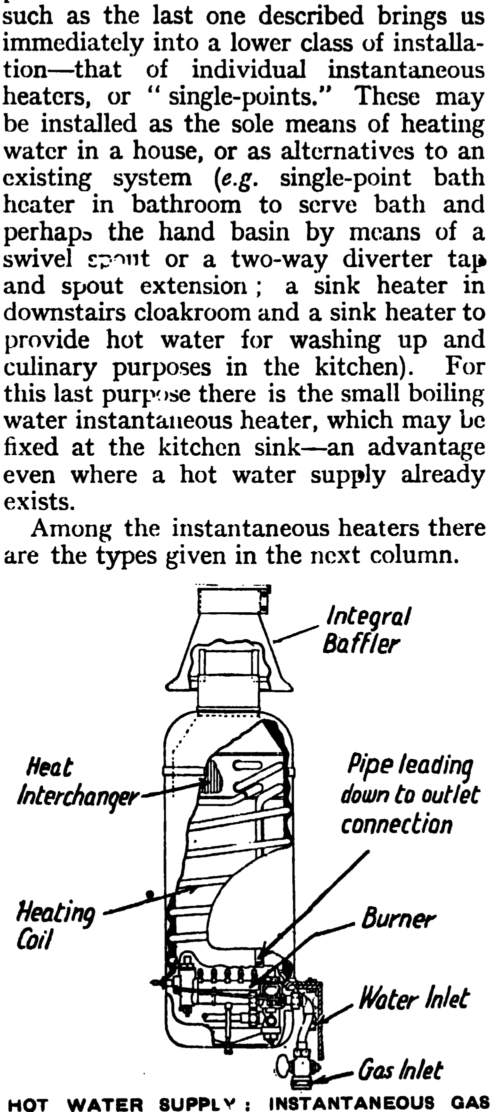
Granting, then, that "full hot water service at several points" can be given only by a properly chosen multi-point storage system (with circulation), what is the proper application of the instantaneous heater?

The nearest approach to full service is given by the instantaneous multi-point heater (non-storage)—*see* Fig. 1. This can provide a restricted service to several

taps (but generally not to two taps at the same time) from a central source, giving unlimited hot water, but at a lower rate of flow than is possible with a storage system.

Such heaters are especially suitable for multi-point service where there is limited space, where a more or less continuous flow over fairly long periods is required, and where the usage is relatively small and intermittent. In the latter instance it must not be forgotten that economies in intermittent use may be made by the separate operation of a local sink heater plus a local bath heater. An installation such as the last one described brings us immediately into a lower class of installation—that of individual instantaneous heaters, or "single-points." These may be installed as the sole means of heating water in a house, or as alternatives to an existing system (*e.g.* single-point bath heater in bathroom to serve bath and perhaps the hand basin by means of a swivel spout or a two-way diverter tap and spout extension; a sink heater in downstairs cloakroom and a sink heater to provide hot water for washing up and culinary purposes in the kitchen). For this last purpose there is the small boiling water instantaneous heater, which may be fixed at the kitchen sink—an advantage even where a hot water supply already exists.

Among the instantaneous heaters there are the types given in the next column.



HOT WATER SUPPLY: INSTANTANEOUS GAS HEATERS. Fig. 1. "Cal-font de Luxe" instantaneous multi-point non-storage heater, giving unlimited hot water to restricted number of taps at lower rate than from storage system. (*Ewart & Son, Ltd.*)

(*a*) Multi-point heaters with outputs varying between 1½ gal. per minute to 3½ gal. per minute, raised 40° F.

(*b*) Single-point bath heaters with outputs varying between 2½ gal. per minute and 3½ gal. per minute, raised 40° F.

(*c*) Single-point sink heaters with outputs of about 1 gal. per minute, raised 40° F.

(*d*) Single-point boiling water appliances capable of delivering hot or boiling water (in some designs the appliance is arranged so as to deliver boiling water ONLY) with outputs varying between 2½ pints of boiling water per minute (from 60° F.) for the domestic size, to outputs as high as 12 pints per minute in the restaurant sizes.

Multi-point Heaters. Reviewing the four classes, it must be explained in the case of the multi-points that so low a flow as 1½ gal. per minute raised 40° F. would be tolerated only by those who realized that such a service was the best compromise between what the consumer could afford and what should really be supplied. The relatively slow delivery at the bath is an obvious disadvantage, but one which may easily be over-emphasized, as it is often much less obvious to those who hitherto have had no hot water on tap than to people used to a quicker service.

It should be remembered, too, that the small multi-point will give a bath more cheaply and in half the time required with the cheapest alternative means—the wash boiler. Small multi-point heaters are operating very satisfactorily in blocks of artisan flats.

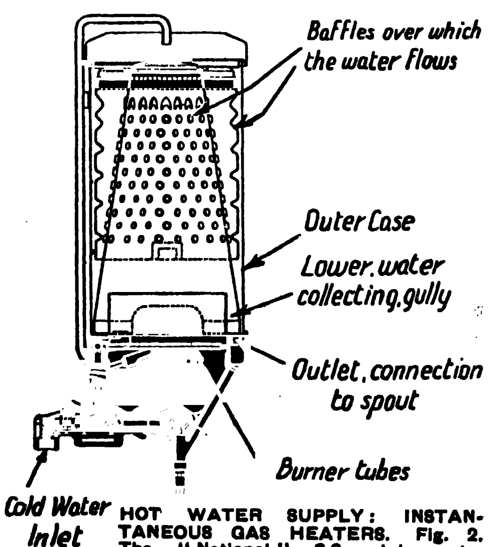
As to the larger sizes, the upper limiting rate of flow already indicated suffices for domestic installation, although some years ago very large multi-points were installed and used for jobs really more suitable for large storage heaters.

Multi-points are of the closed pressure type, and generally consist of a coil, part of which forms a finned heat interchanger; the modern types will supply taps at any part of the house so long as there is sufficient head to operate the automatic gas and water valves, although some of the earlier models (*e.g.* the "broken feed" type) depended on a gravity flow of outlet water to the taps, and therefore had to be fixed as much above the taps as possible so as to ensure a reasonable outflow of hot water at those taps.

Single Point Heaters. The original "single points" for bathrooms consisted merely of a copper drum-shaped body down and through which water cascaded over baffle plates, to collect at the bottom

and so flow out of a spout and into the bath. The gas products flowed upwards across the same baffle plates, mixing and being in the same compartment as the water itself until they left the appliance at the top flue outlet. These heaters maintained a high thermal efficiency, were cheap to manufacture, and very easy to maintain. They became unpopular owing to the fact that deposits (copper salts) were allowed to be carried into the bath, staining the surface of the bath and sometimes the water itself—quite apart from the fact that they were not fitted with automatic valves or, in many cases, even with interlocking taps. Singularly enough however, the "open" type single-point instantaneous heater is very much in use again today in the form of a sink heater. The S.S. sink water heater (*see* Fig. 2) is most simple in design and maintenance; it avoids internal corrosion by having internal baffle plates of aluminium, over which the water flows downwards to the outlet.

With this exception we may take it that most single-point heaters are of the closed type. Some models had elaborate overflow water chambers, but today the coil type seems to be as popular. A further differentiation is between those with a "broken feed" water connexion and those which are designed to withstand the full pressure of direct connexion to a main water supply. Undoubtedly the latter



HOT WATER SUPPLY: INSTANTANEOUS GAS HEATERS. Fig. 2. The "National" S.S. sink water heater, open type single-point; avoids internal corrosion by the use of aluminium baffle plates.
National Gas Water Heater Co., Ltd.

types make for the neatest appearance, but the "broken feed" type is generally much simpler in valve construction, etc.

Boiling Water Heaters. These are not so numerous as the ordinary instantaneous heaters, since until recently no

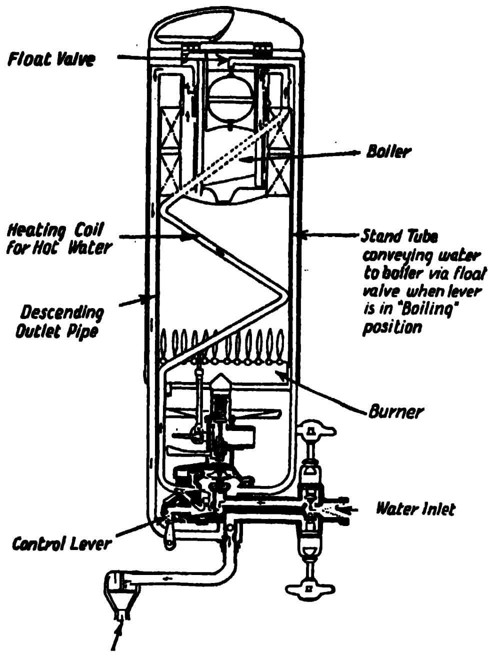


Fig. 3. "Ascot" R.S. 52 water heater, instantaneous single-point sink heater with provision for supplying boiling water.
Ascot Gas Water Heater, Ltd.

effort has been made to place them on the domestic market. Today, however, the small-output heaters are being largely utilized for tea making, being quicker and more efficient in use than kettles; while in restaurant work the only way to provide for a good class tea demand is to use small teapots, one for each small group of customers, and to brew tea in each pot as and when required, with freshly boiled water from a boiling water heater. As it is to be expected, these machines are more expensive than their hot water counterparts; they have to withstand greater wear, need some special "boiling water only" valve, and have to be made readily accessible for de-scaling (*see* Fig. 3).

B. CHOICE OF SYSTEM: RUNNING COSTS

In deciding the size of instantaneous water heaters to be recommended, the general answer should be "the quickest heater that the customer can afford";

but the following points also affect the final choice:

1. Shape and size of heater in relation to space and position available for fixing—and especially for making a good secondary flue connexion.
2. Lower gas rate (*i.e.* slower heating) may enable change of meter, supply pipes, etc., to be avoided and reduce possibility of adverse effect on other appliances in the house.
3. Economy and neatness in fixing—size of connexions, flue pipe.
4. With multi-point heaters the smaller the heater the more economical its use at the sink, owing to the smaller thermal capacity of the heater and its contents.

On the question of running costs it is a mistake to assume that gas is a luxury rather than a utility fuel for domestic water heating; and that of the two gas water heating systems (storage and instantaneous) the former is necessarily much more expensive. Everything depends upon whether the right system has been installed for the particular job.

Actually we can say that storage and instantaneous heaters cost about the same to run. Where hot water is required in small amounts at infrequent intervals, instantaneous heaters are more economical. For households with medium requirements they are probably somewhat more economical, while for larger requirements there is little difference *for a given quantity of water*. A quick heating storage system tends to greater use of hot water (*i.e.* fuller service), with resultant increased cost. It is possible, however, to overstress the importance of running costs for many people, though it must not be under-estimated in dealing with those of lower incomes.

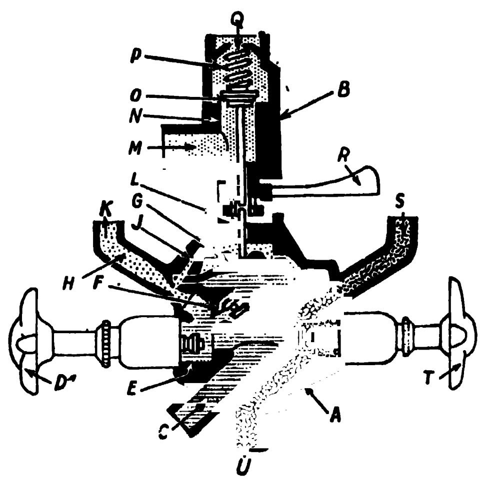
It is not at first obvious why the differences in running costs of storage and instantaneous water heaters are small, though practical tests confirm this, since it is frequently urged in favour of instantaneous heaters, irrespective of the service required, that

(*a*) The pilot consumption is negligible, or at least small, while storage heaters require an appreciable by-pass consumption.
(*b*) Heating efficiencies are higher.
(*c*) Heat losses inseparable from a storage system are eliminated.

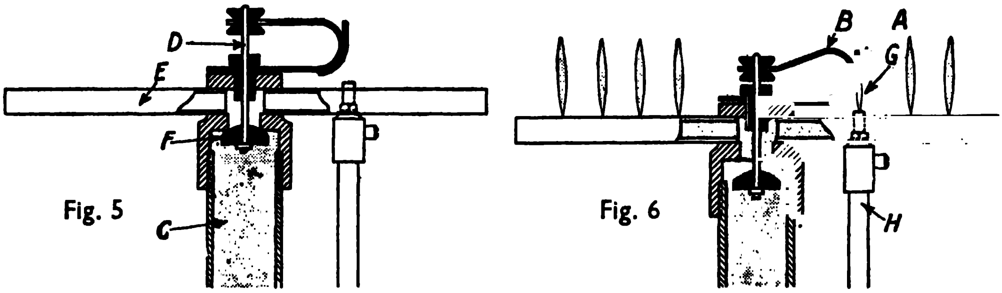
All this is true, but (*a*) and (*b*) are really the same point, while all efficiencies today are very high and the variation between the two types is not considerable. Other points to consider are the fact that each time an instantaneous heater is used starting from cold, heat has to be supplied to heat the appliance itself before the water is fully heated; multi-point heaters working on a fluctuating main water pressure can also give relatively low overall efficiencies, because of waste during the period of adjustment, especially when pipe runs are long. (Heaters with water governors overcome this disadvantage.) With any hot water system, if the pilots are left alight (as they must be for good service) or fuel is burned to keep stored water hot, and if only very small quantities are drawn, the overall cost per gallon of hot water will be abnormally high.

C. VALVES ON INSTANTANEOUS WATER HEATERS

Automatic valves (*see* Figs. 4–8) are employed on all types of instantaneous water heater for two main reasons: first to provide automatic opening of the gas valve when water is drawn; and secondly to act as a safety device by preventing gas reaching the burner unless there is a certain minimum flow of water. An entirely automatic and foolproof appliance is obtained by the use of interlocking taps to prevent the main gas supply to the burner being turned on unless the pilot tap is turned on, and in multi-point heaters a thermal cut-off is provided which closes the main gasway if the pilot flame becomes extinguished.



HOT WATER SUPPLY: INSTANTANEOUS GAS HEATERS. Fig. 4. Automatic valve for "Ascot" single-point gas water heater, R 12/4: A, water section; B, gas section; C, cold water inlet; D, hot water tap; E, high pressure duct; F, slow ignition valve; G, rubber diaphragm; H, venturi; J, low pressure duct; K, cold water outlet to body; L, push rod; M, gas inlet; N, gas cock plug; O, gas valve; P, gas valve spring; Q, gas outlet to burner; R, gas cock handle; S, hot water inlet from body; T, cold water tap; U, open water outlet.
Ascot Gas Water Heaters, Ltd.



HOT WATER SUPPLY: INSTANTANEOUS GAS HEATERS. Figs. 5 and 6. "Ascot" pilot safety device: (5) pilot flame out, gas valve closed; (6) pilot flame alight, gas valve open. A, protective cover; B, bi-metal spring; C, gas inlet; D, connecting rod; E, burner tube; F, gas valve; G, pilot flame; H, pilot. (*Ascot Gas Water Heaters, Ltd.*)

There are two points in connexion with these valves which require elucidation: the determination of the "minimum water flow" and the "minimum permissible head."

Minimum Water Flow. The choice of the "minimum water flow" is affected by:

(i) Gas rate of heater, determining the temperature rise at minimum flow.
(ii) Inlet water temperature fluctuations.
(iii) Purpose for which water is required.
(*ii and iii determine the necessary temperature rise.*)
(iv) The hardness of the water.
(v) The construction of the heater.
(*iv and v determine the allowable temperature rise.*)

In the London area, at least, it now appears to be generally agreed that an adequate temperature rise above the cold inlet water temperature (this may vary between 35° F. and 65° F.) is 100° F. If the temperature rise were allowed to exceed this limit, maintenance would be increased, owing to the heavier scale formation, and the life of the heater would be reduced by overheating; the possible effect of internal bursting forces due to local steam formation must be reckoned with.

Usually valves are not manufactured as proportional gas and water rate controllers (although such systems are in use), but are designed to open the gas way only when a certain flow (corresponding to about 100° F. rise) at the correct

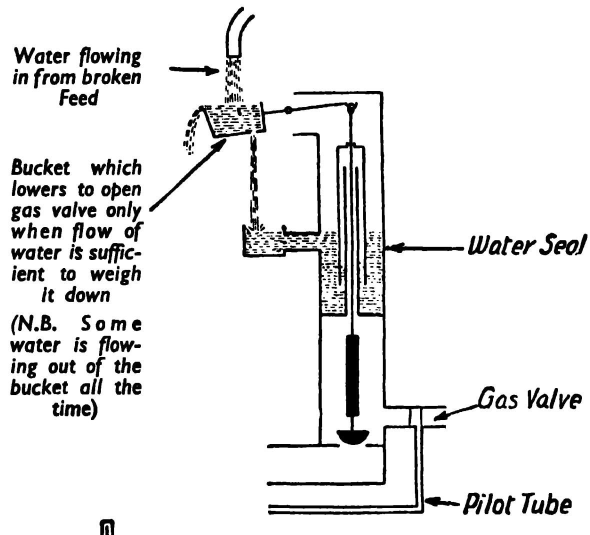


Fig. 7 (above). Low head bucket valve, suitable for an instantaneous single-point bath heater: opens only when weight of water in bucket is sufficient.

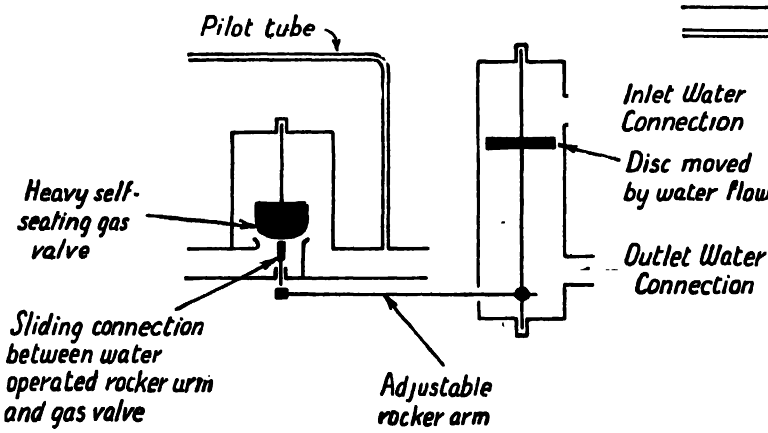


Fig. 8 (left). "Califont de Luxe" multi-point water heater valve operated by disc which is moved by water flow. *Ewart & Son, Ltd.*

gas rate is reached. Sometimes these valves, when operating near the limit of minimum water flow, are very susceptible to fluctuations in the inlet water pressure, so that wherever possible it is wise to fit the heaters on the down feed of an ample cold feed tank. (N.B.—Even with tank supplies the outlet pipes should be of adequate bore and should not be overloaded.)

Minimum Permissible Head. Referring now to the question of "minimum permissible head," it should be said at once that all makers try to reduce this limiting factor of installation as far as is possible and consistent with the use of adequate force for the safe and certain closing of the gas valve. Thus, although lower heads might be possible with certain heaters, these would only be obtainable by reducing the reliability of the valve (*e.g.* by using weaker springs) or by increasing the cost of the appliance through using larger diaphragms.

As water flows from the inlet to the outlet of an appliance or valve mechanism, a certain amount of pressure is lost through overcoming the resistance in the waterways; it is this pressure loss (at the time when a full gas rate is just reached) that is known as "the minimum head required to operate the valve" or the "minimum permissible head." (It should be noted that most valves require a rather greater flow to open them than is required to keep them open. Hence, to obtain the highest temperature rise, the draw-off should be opened just sufficiently to open the valve and then it should be slightly closed again to a point where the absolute minimum flow is reached.)

It is essential that the maker's data sheet should quote the minimum head to operate the valve; but even when this has been read and duly noted the appliance must not be installed without due regard to the effect of pressure losses in the pipe runs, stopcocks, fittings and draw-off taps. In fact, unless the available head (this should be measured as the vertical distance between the cold feed tank and the spout or highest draw-off) is greater than the combined resistance of the valve, waterways, pipes, fittings, stopcocks and taps through which the water has to flow to its first broken point, the valve will not open. It will be seen then that in some borderline cases the valve may be caused to work by running a larger down feed, fitting larger cocks, or even by removing some internal corrosion which has been restricting the water flow.

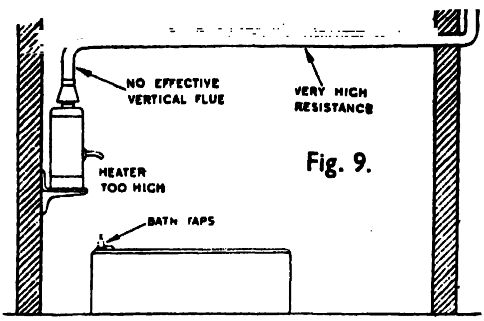
The provision of the minimum permissible head does not imply that the rated output flow from the heater at a 40° F. temperature rise will be obtained. Actually this rating is purely a nominal one for comparison of performance. In actual practice users rarely demand water at so low a temperature as that resulting from a 40° F. rise.

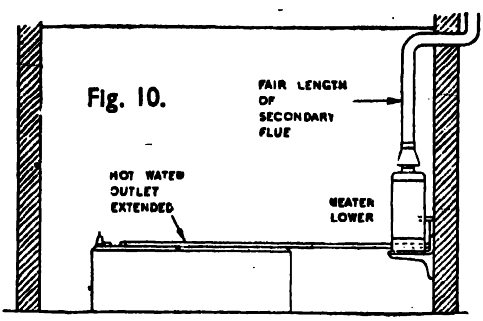
Of the valves themselves, we find that with pressure type appliances (*i.e.* those in which the water supply is unbroken right into the interior of the appliance) the valves are robust and generally spring or weight loaded. With "broken feed" appliances the water flows out from the valve via a broken feed into the appliance. From this point the water flows through the heater by gravity. Valves, however, are sometimes embodied in the heater itself, and water flows into them from the broken feed. These types are generally found in earlier models, although their simplicity and need for very low operating heads make them indispensable in certain jobs today. Multi-point valves operated by the flow of water through a venturi throat or across an orifice are designed to be operated by a closing outlet; but in the case of valves used on certain single-point heaters which may be of the spring loaded pressure operated type, the outlet should not on any account be closed or restricted. The use of pressure operated valves with fixed open outlets is common, as such valves are cheaper to manufacture.

Most modern valves embody some slow-ignition device, often in the form of a restricted flow for the water passing into the loaded diaphragm, while on the multi-points a thermal cut-off operating on the bi-metallic principle is generally an integral part.

D. FIXING INSTANTANEOUS GAS WATER-HEATERS

Any gas water heating appliance, when fitted, should have an adequate gas supply, an adequately sized meter and adequate water supply. Also, if the conditions and gas rate of the heater demand it, it needs an adequate flue





HOT WATER SUPPLY: INSTANTANEOUS GAS HEATERS. Figs. 9 and 10. Fixing single-point heater to supply bath: (9) bad arrangement with long horizontal and inefficient secondary flue; (10) improvement brought about by extending outlet from spout in copper tubing so that heater is against external wall, and by lowering heater to allow longer secondary flue.

installation. Details of standard gas-fitting practice and of the cold water supply are covered elsewhere in this work (*see* Gas Fitting; Cold Water Supply; Flues), so that with the exception of one or two flue details no further information need be given here. Certain details peculiar to the installation of Instantaneous Water Heaters will be discussed, however.

Fixing Single-Point Heaters. The heater should be so placed that there is sufficient head to operate its valve. The heater should be kept as low as possible, as this has the advantage of allowing a useful height of secondary flue pipe and also brings the spout nearer the bath. With the spout, however, it is not essential that it should come at the tap end of the bath. To provide for this would often involve the need for a long horizontal run of secondary flue, whereas by fixing the water heater as near to the outside wall as possible in every case, a short flue with a minimum of resistance to the flow of the outgoing products is assured. It is very much better to extend the spout and shorten the flue, as may be seen in Figs. 9 and 10.

Alternatively, a multi-point can be used to perform the duty of a single-point heater by serving a single outlet tap over the bath; in fact, the multi-point need not be in the bathroom at all. This is also a very useful arrangement where there is no outside wall or window in the bedroom, or where it would be difficult to run the flue from the bathroom.

The spout extension already mentioned would be run in ¾-in. B.S. light gauge copper tubing, and would be joined to the existing spout (shortened) by means of a ¾-in. copper capillary union (*see* Fig. 11). In some cases special bushes will be required, but the illustration shows with what ease such an extension can be made for a G.L.C. Single-Point Water Heater. The copper tubing should be chromium plated after setting into shape.

A further development associated with the extension spout idea is the two-way adapter, designed for use when more than one point is to be served by a single-point heater. In use it is intended to supply hot water alternatively to a bath and lavatory basin in the same room, but can, of course, be utilized in other combinations, such as serving the kitchen sink (over which the heater would probably be fitted, since the greatest use of water will probably be at that point) and the bath in an adjacent room. It would do scanty justice to a gas installation

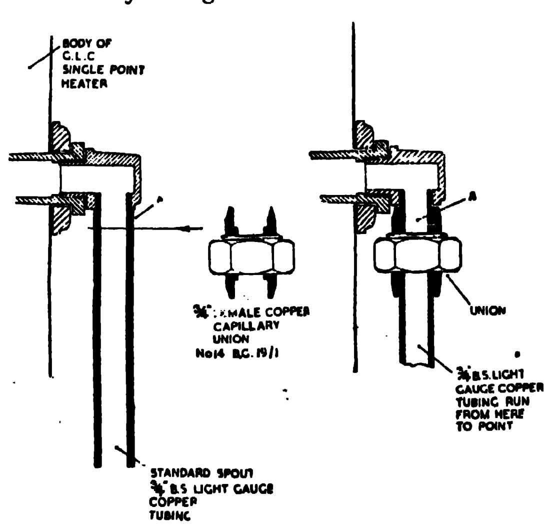
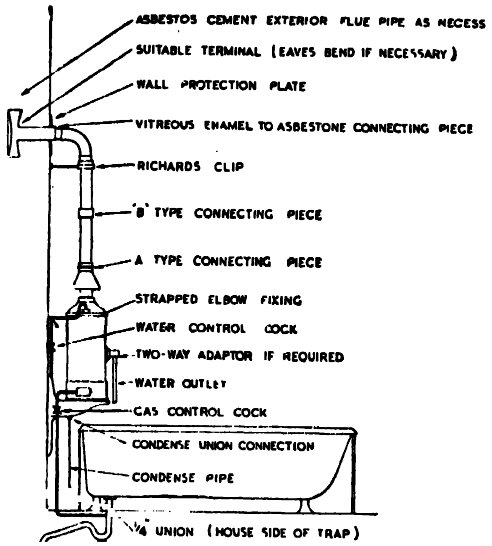


Fig. 11. Method of adapting standard copper union to extend outlet away from "G.L.C." single-point heater.



HOT WATER SUPPLY: INSTANTANEOUS GAS HEATERS. Fig. 12. Typical installation of a single-point instantaneous water heater, showing heater fixed to wall over bath. The various parts and fittings for flue are indicated.

however, if such an arrangement were suggested before it was quite certain that superior alternatives (*e.g.* multi-point or storage heaters) were unacceptable to the prospective user.

The G.L.C. adapter can be screwed straight into the spout tapping of the G.L.C. Single-Point Water Heater, leaving two unions to which the original spout and the extension are screwed respectively. The unions are reversible, so that either a left-hand or a right-hand connexion may be taken from the heater. As water will only feed to the extension spout by gravity from the heater, the whole run of the extension must be below the spout connexion in the heater. Bends should be as gradual as possible; there should be no dips or traps in the tube which might cause an air lock, and the end of extension piece must always be *open*. In some cases, for a neat appearance, the extension could be connected to an existing basin tap, but only after the jumper of the tap had been removed so that it could not be shut off. It is impossible to shut off the outlets from the two-way adapter completely—one connexion is always open.

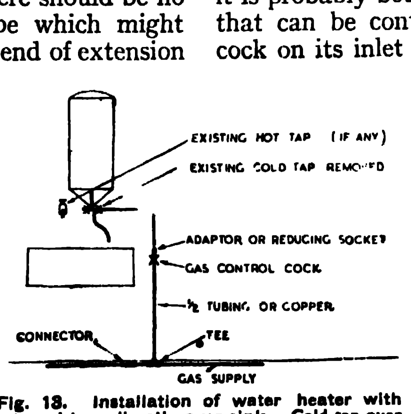


Fig. 13. Installation of water heater with integral taps directly over sink. Cold tap over sink is removed but existing hot tap is left intact.

In arranging the installation of single-point bath heaters many points come under review, but Fig. 12 will serve as a reminder of the principal items required. Although this diagram does not serve for multi-point heaters, the fixing of the latter with their iron, copper or lead gas and water connexions is really straightforward gas fitting or plumbing work, and flue practice is standard. Details of multi-point systems will be given later in connexion with their installation as alternative methods of providing hot water to taps served by solid fuel systems.

A special item with regard to single-point heaters (namely, disposal of condensation) will now be dealt with. (N.B. Some modern single-point heaters and most multi-point heaters do not condense.) Condensation should be disposed of in one of the three following ways (preferably by the first method):

(*a*) Into the house side of the trap in the waste pipe from the bath or basin.

(*b*) Through the wall to discharge above an open hopper head.

(*c*) To a condense pot (to be emptied by hand before it becomes too full).

With the first two methods a ¼-in. union should be provided to facilitate disconnexion of the pipe for cleaning.

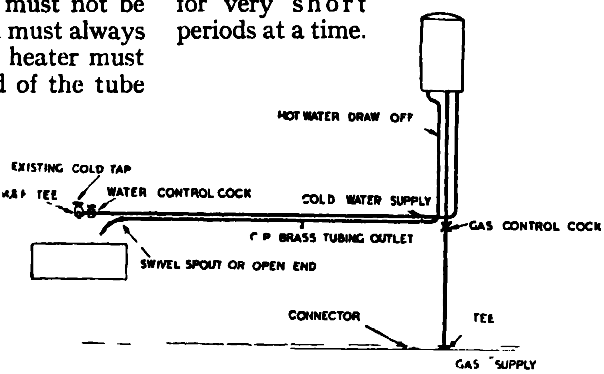
Sink Heaters. We must now consider the fixing of the instantaneous sink heaters. For some types it is normally only necessary to remove the cold water tap over the sink and connect the heater in its place (Fig. 13). Such heaters have cold and hot taps as integral parts, so that the original cold tap is not used as such. Where, however, it is impracticable to fit the heater over the sink, it is probably better to fix one of the type that can be controlled by a small stop-cock on its inlet (this cock can be placed over the sink near the cold water tap).

An extension spout is run back from the heater to the basin (*see* Fig. 14) and terminated with a neat open bib. Swivel spouts allow a single heater to serve two adjoining basins, but unless the heater is of the pressure type and specially sized connexions and fittings are used, spray

attachments should not be recommended. In any case, when a spray attachment or rubber extension is fitted, it must not be on to a main water supply but must always be taken from a tank, or the heater must be so fitted that the rose end of the tube cannot dip into the basin.

Figs. 13 and 14 show methods of fixing the two types of heater referred to above, the principal fittings being named for guidance in estimating. Where a sink heater is fixed in front of a window its weight may easily be taken by a neat batten screwed across the window, level with the supporting lug on the heater.

necessary, as the gas rates rarely exceed 60 cu. ft. per hour and then operate only for very short periods at a time.



HOT WATER SUPPLY: INSTANTANEOUS GAS HEATERS.
Fig. 14. Alternative installation to that of Fig. 13: here it is not possible to fix heater over sink, so the outlet is extended as shown; stopcock is fitted on inlet pipe near existing cold tap.

E. VENTILATION OF INSTANTANEOUS HEATERS

As instantaneous heaters have the highest hourly gas rates of all the domestic appliances (though these high rates are only intermittent), and are often fixed in comparatively small rooms, adequate ventilation for the size of room and heater should be provided with every installation. The outlet ventilation will be provided by a flue pipe in the larger installations; but with sink heaters (which generally are not fixed in bathrooms) flues are unnecessary.

The general functions of a complete flue installation have been described (*see* Gas Fitting) earlier in this work, and mention made of recommendations contained in the "1937 Regulations" issued by the Institution of Gas Engineers. The fixings for flues, the positioning of terminals, etc., have also been covered, but the following clause of the Regulations sometimes involves additional fitting in the form of an air brick or special air inlet:

Clause 16.

(*e*) Any appliance fitted in a bathroom for heating water for a bath, having gas burners, generating more than 500 B.Th.U. (gross) per hour per 35 cu. ft. of room space. Every such bathroom shall in addition be provided with adequate means of ventilation to the outside of the room by sufficient aperture or air shaft having an unobstructed sectional area of not less than 15 sq. in.

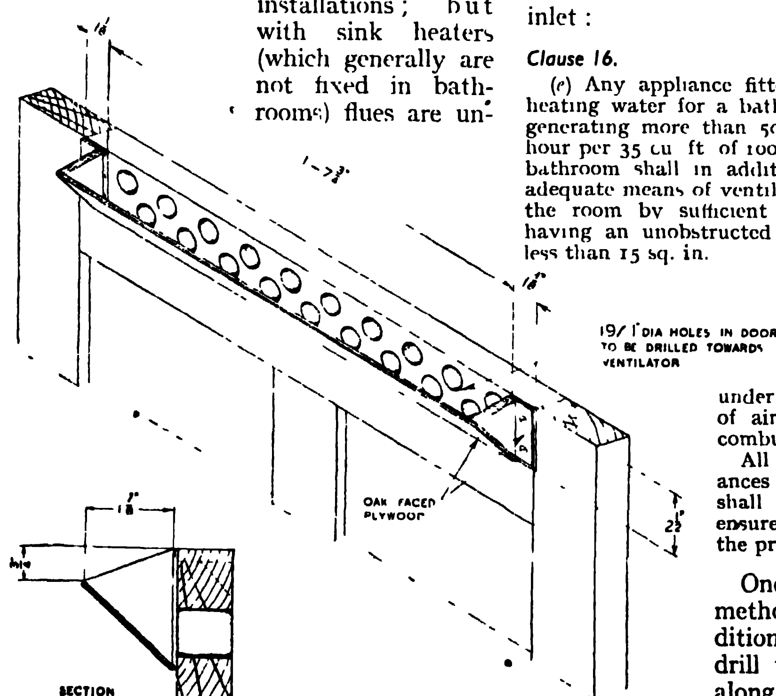


Fig. 15. Ventilation drillings in top of bathroom door, with cover plate fitted to conceal holes; (left) section through door and plate.

NOTE.—All water heating appliances, whether fitted with a flue or not, shall be so placed as to ensure under all conditions a supply of air sufficient to support combustion.

All water heating appliances not fitted with a flue shall be so placed as to ensure the free discharge of the products of combustion.

One of the simplest methods of providing additional ventilation is to drill the bathroom door along its top (*see* Fig. 15). A cover plate can be made to hide the

drillings, which can be of 1 in. diameter. The cover may be fixed to either side of the door, but it is better to have it on the outside; if fitted inside, it will deflect any draught towards the ceiling.

Other methods of additional ventilation have been adopted, such as leaving an annular space around the outgoing flue-pipe, or preventing a window from ever being completely closed; but probably the air brick is the most accepted practice and, after all, is a lasting job.

F. INSTANTANEOUS WATER HEATERS AS ALTERNATIVES TO EXISTING SOLID FUEL WATER HEATING SYSTEMS

Instantaneous water heaters were probably first intended to be fixed as individual appliances in bathrooms, as alternatives to the existing solid fuel systems; the latter, in many older houses, were notorious for their unreliability, inadequacy and running cost. Today, however, when considering an alternative system, we have in mind rather an up-to-date solid-fuel system to the pipe runs of which an instantaneous multi-point gas water heater can be connected, so that when the boiler is out of commission a supply of hot water can be drawn at the taps merely by opening or closing certain control valves. In the small kitchens of today, often run without a maid, such an arrangement is of great advantage. If the fire goes out, if the house has been left for the week-end, or if the solid fuel boiler in the kitchen is let out in warm weather, there is always the alternative gas-fired heater connected up and ready to serve all taps at once.

Before going on to detailed points concerning alternative systems, there are three general warnings which must never be overlooked:

(*a*) Remember that in a properly arranged solid fuel circulating hot water system the water supply should feed from a cold storage tank, fixed in a position above all the draw-off taps; and an expansion pipe should be run up from the top of the storage vessel. With regard to this open expansion pipe it is essential that the head of water serving the multi-point heater should not be greater than that from the cold feed tank; otherwise, when the cold supply to the multi-point came to be turned on and the valve connecting to the storage system was open, water at the higher pressure would flow straight through the multi-point and up and out of the open end of the expansion pipe. This really means that the cold inlet water supply for an alternative multi-point water heater connected up to an existing system must come from the existing cold feed tank. In best practice, this supply would be by means of a separate down feed pipe.

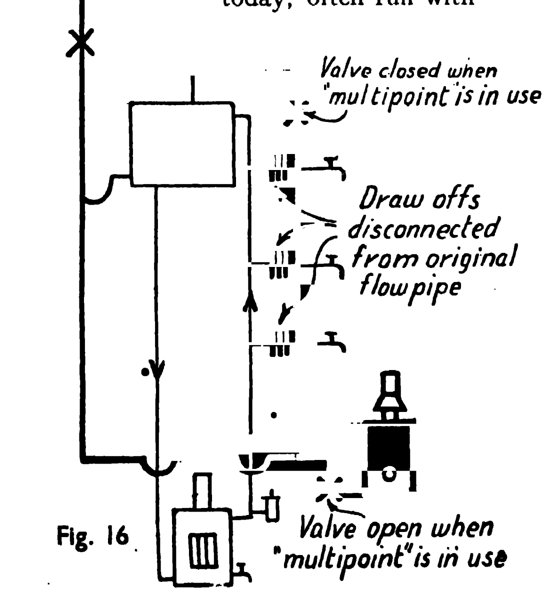


Fig. 16

HOT WATER SUPPLY: INSTANTANEOUS GAS HEATERS. Fig. 16. Conversion of existing tank system into cylinder system served by multi-point heater: new pipework shown by heavy lines.

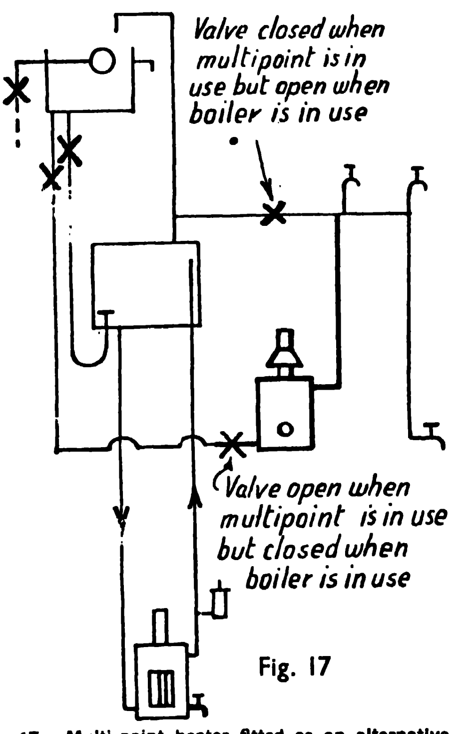


Fig. 17

Fig. 17. Multi-point heater fitted as an alternative to an existing cylinder system: change-over valves are provided so that either system can be used: new pipework shown by heavy lines.

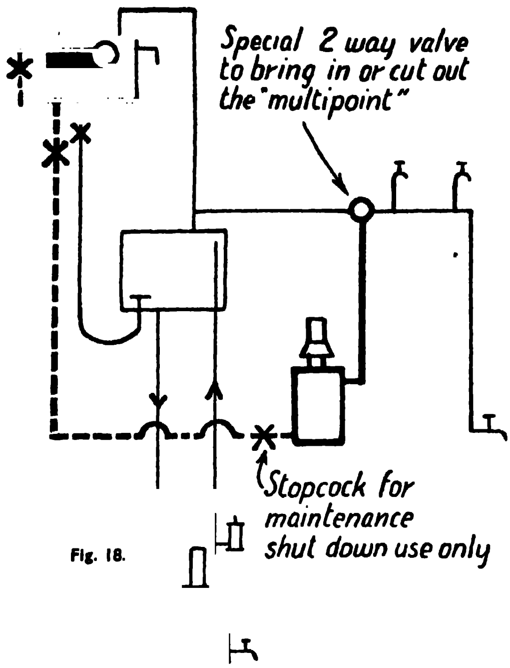


Fig. 18.

HOT WATER SUPPLY: INSTANTANEOUS GAS HEATERS. Fig. 18. Another method of fitting multi-point heater as alternative to existing cylinder system (*compare* Fig. 17), with one two-way valve for change-over. New pipework in heavy lines.

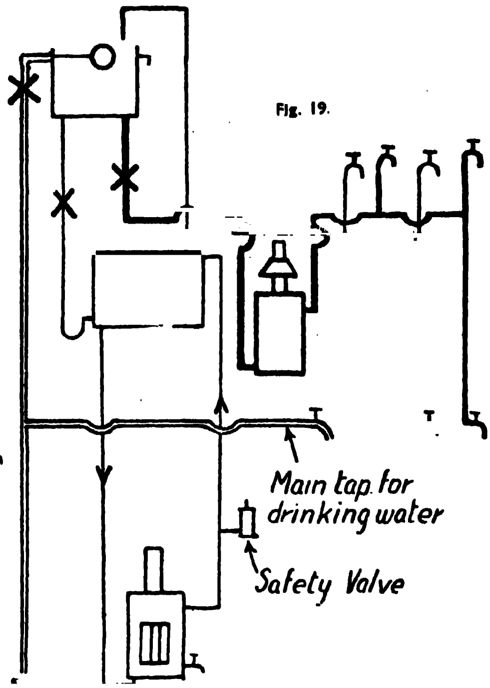


Fig. 19.

Fig. 19. Multi-point heater fitted to cylinder system: as explained in text, change-over valves are unnecessary, since cold water can be drawn from certain taps no matter which heating unit is out of commission. Heavy lines indicate new pipework.

(*b*) The effect of (*a*) is that the water supply for the multi-point must not come directly from the main service. Hence a careful check must be made to ascertain whether the head from the cold feed tank is sufficient to operate the automatic valve of the heater. If the head is not great enough, then the cold feed tank should be raised so as to provide the necessary pressure. It should be noted that in measuring the head available, the distance between the cold feed tank and the automatic valve of the heater does not give a true figure. The true minimum operating head is the distance between the *highest* draw-off tap and the cold feed tank. (To make sure of some margin it is recommended that the measurement be taken from the bottom of the tank, in case the tank nearly empties itself during use.)

(*c*) In alternative systems as few valves as possible should be used, since numerous valves tend only to confuse the average householder. Some valves are necessary, however, but none should be fitted in positions where, if they were closed, they would interfere with the free circulation of water in the storage system, or the free passage of the expansion pipe. Actually, even if the control valves were set to serve the taps from the multi-point, it should be possible for a full fire to be alight in the solid fuel boiler without any fear of danger from stopped flow, return or expansion pipes.

The above considerations govern the fixing details of these alternative systems, and it will be realized that it is almost impracticable to connect up a multi-point heater to a tank system unless there is only one tee in the flow pipe from which supplies to the draw-off taps are taken.

Four explanatory diagrams are given in Figs. 16 to 19. The first shows the conversion of an existing tank system into a cylinder system, so that a multi-point heater can be connected up to serve the same draw-offs.

The second diagram (Fig. 17) shows a simple method of fixing a multi-point as an alternative on an existing cylinder system. Fig. 18 shows the application of a special two-way control valve which leaves the householder with only one valve to turn when he wishes to change over from one means of water heating to the other.

To obviate the need of change-over valves altogether, certain gas undertakings and contractors prefer an installation such as that indicated by the fourth illustration (diagram, Fig. 19). With this method two taps are retained at the bath and hand basin, but at the sink a third main supply tap for drinking water is provided. By this provision it does not matter if all the other taps in the house are served by two separate water heating systems, as indeed they are. Thus in the winter, hot water would be supplied to the left-hand taps from the solid fuel system,

and cold water to the right-hand taps via the multi-point (with gas turned off and the heater out of use for the time being); while in summer the multi-point could be lighted up and the right-hand taps supplied with hot water while the left-hand taps served as cold taps (the solid fuel boiler being temporarily out of commission, of course).

G. MAINTENANCE OF INSTANTANEOUS WATER HEATERS

Instantaneous heaters, as their name implies, are designed to be put into full action instantly, and because they produce hot water by a large expenditure of energy during the short time that the water is flowing out of the appliance, it might be thought that wear would be excessive. In actual practice it is found that little trouble need be feared on this score, however. Recent "life" tests, operated by turning the appliances on and off mechanically at regular intervals for weeks at a time, have demonstrated that most heaters of this type may be left to run for two years at a time without being touched in any way. Gas undertakings conducting periodical maintenance inspection visits generally arrange for one inspection per annum.

At such an inspection the following work would be carried out:

(*a*) Light up the appliance with water flowing and examine the state of the flames, and test the operation of the flue.

(*b*) Examine the gas and water taps; exchange washers where necessary.

(*c*) Examine the condition of the flue pipe, baffler and terminal, clean them and renew them if any sign of severe corrosion is apparent.

(*d*) Check over the general condition of the heater and renew jets or burners where necessary. Clean the burner and interior of the heater.

(*e*) Disconnect the condensation pipe (if any), clean it throughly and all its connexions and make sure that there have been no leakages draining away from the interior of the appliance.

(*f*) See that the lighting instruction plate is in place and in good condition.

(*g*) Make sure that the heater is securely fixed on its bracket or wall fixing, and also that the flue pipe and fittings are safely held.

(*h*) Charge the appliance with water and watch for water leakages.

(*i*) Having turned off the water, light the pilot (testing the thermo. cut-off, if any). Turn the gas cock full on and then turn on the water (*i.e.* if automatic valve is fitted).

(*j*) Test the action of the automatic valve by turning off the water, when the burner flames should be extinguished.

(*k*) Once again observe the condition of the flames and test the operation of the flue.

(*l*) Finally, check the water flow and particularly the gas rate. The gas rate may often be roughly set by using a pressure gauge at the burner pressure point, but the final check should be by means of the meter test dial and the seconds hand of a watch.

It will be noted that there is no mention of dismantling or cleaning the automatic valve among these suggestions; but unless there is a definite complaint, the only point that might be looked at is the water filter fitted to its inlet.

Valve complaints, which really are extraordinarily infrequent, should be dealt with by an experienced fitter, specially trained for his job. The major work to be carried out by the inspection fitter is the cleaning of the burner, interior, and flue of flue deposits.

HOT WATER SUPPLY: (5) BY ELECTRICALLY HEATED APPLIANCES

There are three main methods of heating water by electricity for hot water supply: by instantaneous heaters, by thermal storage heaters, and by immersion heaters. Instantaneous electric water heaters heat water as and when it is required in the same manner as does a gas geyser: they have no storage capacity and must warm the water during the comparatively short period of its flow through the apparatus. Very few electricity supply companies will permit their use, since they are an uneconomic load. They need a tremendous current flow for short periods at wide intervals. Consequently they require the mains, meters and all associated apparatus to be large enough to deal with a peak load which seldom occurs. A simple example will make this matter clear: it is evident that if 20 gal. of hot water are required for a bath, the heating of the water over a period of, say, 3 hours (as in a thermal storage type of apparatus) will require an electric current flow only 1/18th of that required if the heating period is 10 minutes (*i.e.* in an instantaneous heater). For this reason self-contained electric water heaters are always of the storage type, although in outward appearance and the pipe connexions they may be similar to a gas geyser.

Thermal storage water heaters and immersion heaters are each dealt with under their own headings. *See therefore* Immersion Heaters; *and* Thermal Storage Heaters.

HOT WATER SUPPLY: (6) PROBLEMS AND DIFFICULTIES

By Frank Herod, M.R.San.I., R.P.
Editor, 'The Plumbing Trade Journal'

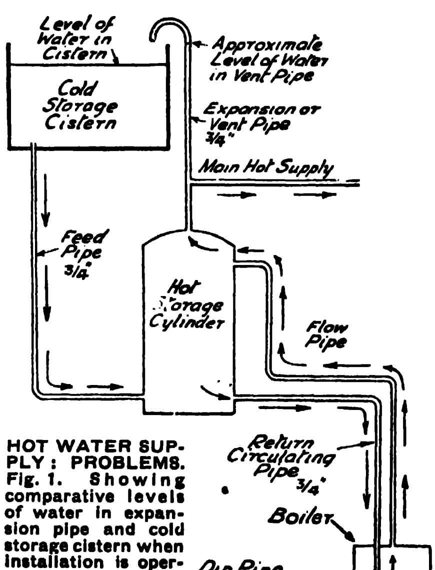
Here, after setting out in simple language the essential rules governing the functioning of a gravity circulation, Mr. Herod discusses certain snags encountered by the hot water fitter mainly in the smaller type of installation. Special notes are included on fire-back boilers. For other information see the articles of the Boiler group.

Unsatisfactory hot water supply installations cause more inconvenience and annoyance, perhaps, than any other department of the plumber's work, and there is abundant evidence that such installations are much too common. Further, in many cases, plumbers sent to correct the faults in such installations often fail to do so.

Essentials for Good Functioning. The failure to install satisfactorily, or to correct faults, arises either from carelessness or from ignorance of the natural laws governing the gravity circulation of a hot water installation. Those laws have been stated elsewhere in this work (*see* Heating *and* Hot Water), but it will be as well to repeat them here. Put in simple language, they are:

(1) A good supply of hot water at taps cannot be obtained unless we first have an adequate cold water supply. In every case, therefore, the cold feed pipe *must* be at least equal in bore to the hot main draw-off.

(2) All waters contain, in varying proportion, dissolved gases; these are released as the water passes through the boiler, and enter the "flow" circulating pipe. The circulating pipes must therefore be arranged so that the released gases can pass up the flow pipe, through the storage cylinder, and out through the vent pipe or expansion pipe. It follows that both flow and return pipes must be laid with a direct fall from the hot storage tank cylinder or to the boiler, and no arch or dip at any point.



HOT WATER SUPPLY: PROBLEMS. Fig. 1. Showing comparative levels of water in expansion pipe and cold storage cistern when installation is operating.

(3) It may be taken that water from a town's main enters the cold storage cistern at a temperature of about 45° F. The density of water at that temperature is 62·422 lb. per cu. ft., whereas the density of water at boiling point is 59·769 lb. per cu. ft. This means that, roughly, 23 gal. of water at 45° F. will fill a 24-gal. tank when heated to boiling point. That difference in density is the *only* motive power in an ordinary gravity circulation, as distinct from the "accelerated" circulation sometimes used on large installations.

The pipes are so arranged that there are two distinct columns of water; what is called the "return" column is definitely cooler (and therefore denser and heavier) than the hot "flow" column. The hot water is *not* forced up the "flow" pipe by the heat of the fire; it is forced up by the colder return column which, by means of the "dip pipe," is delivered near to the bottom of the boiler.

Incidentally, because of this difference in density. the water in the expansion pipe is always (when the installation is at work) at a higher level than that of the water in the cold storage cistern, as shown in Fig. 1.

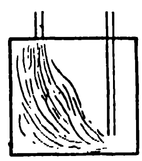
(4) It is essential to select the right type of boiler and set it so as to secure the maximum transmission of heat from the fire to the water in the boiler.

Range Boilers. There are domestic back-boilers (with a central flue passing through the boiler itself) which will supply radiators in addition to giving a good hot water supply, but the present article deals

only with the standard installation for hot water supply in a five or six-roomed house.

Therefore a back-boiler of the "Triplex" type should be selected (*see* page 139) because it is wide and shallow, with good length from front to back, and the flow and return connexions are set widely apart. The best heating surface of any boiler is "bottom heat"—*i.e.* that of the fire itself and the hot flame passing under the boiler. This can be demonstrated at once by holding the hand in an upright position with a lighted match alongside it—and then holding the hand flat with the the match below it.

The importance of traverse in back-boilers is not always appreciated at its true value. When the flow and return connexions are near together, the line of flow from the dip pipe to the flow pipe takes the form of a U, but when those connexions are set widely apart there is a much wider traverse. The entering cold water has a longer travel over the hottest part of the boiler and, as heat transmission is in ratio to the temperature difference between the water and the bottom of the boiler, maximum of heat is transmitted to the water (*see* Fig. 2).



HOT WATER SUPPLY: PROBLEMS. Fig. 2. Traverse of water over heating surface in back-boilers: long traverse (above) providing maximum contact over hottest part; short traverse (below) allowing only short contact.

In most of the grates with which a back-boiler is supplied the position and size of flues are fixed and cannot be altered easily; but failures have occurred even with the best grates, when they have replaced a big old-fashioned range, and the top ends of the flues have been left standing with a wide open space between them and the main chimney flue. There must not be any such space—the flue supplied with the grate must be properly "gathered," by appropriate brickwork, to the main flue of the chimney. The continuous parallel-sided flue is essential whether on new work or alterations, any wide spaces forming "cold air pockets," which cause down-draughts.

When fixing a boiler to an ordinary (non-specialist) range, the plumber must see that the bricksetter forms the flues correctly, giving as much bottom heat as possible, and keeping the top of the horizontal boiler flue at such a level that cold air will not pass *over* the fire and under the boiler until the fire has become very low. The space between the back of the boiler and the brickwork should not be more than 2½ in. across, thus keeping the still hot flame close to its work. Water in the storage cylinder will remain hot much longer if, when retiring for the night and the fire happens to be low, the boiler damper is shut off.

FAULTS IN EXISTING INSTALLATIONS

Having pointed out the snags to be avoided when fixing a new installation, we come to those cases where the plumber is called in to remedy some other plumber's mistakes, and a number are quoted.

Air in Pipes. A plumber was called to a house where the circulation repeatedly stopped through air lock, and no hot water could be drawn. Taking an electric torch, he found that water from the ball valve entered the cistern with great force and splashing. The outgo from the cistern was immediately under the ball valve. As water enters the cistern only when water is passing from the outgo, the air bubbles thus caused could be seen passing into the installation (*see* Fig. 3). The trouble was overcome when the outgo was taken from the opposite end of the cistern. It could have been overcome just as easily by running a "silencer" tube from the ball valve to the bottom and across the cistern; any air which then entered the cistern would rise to the surface instead of entering the feed pipe.

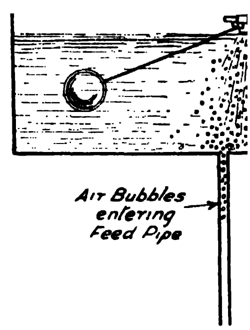


Fig. 3. Air-lock in pipes caused by bubbles entering cold feed pipe from ball valve immediately over it.

In any case, if the installation had been properly fixed, any air entering would have passed out through the vent pipe without causing air lock.

Air Lock in Feed Pipe. Air lock sometimes occurs in feed pipes taken from

the side of a cold feed cistern and carried horizontally for a distance. It is generally only a partial air lock, but often quite enough to make the "feed" insufficient. Air may pass into the feed pipe in the same way as in the previous instance; and, in addition, all water contains some dissolved gas. When this water stands for a time the dissolved gases are released, and collect at the highest point above unless the pipe concerned has a definite rise to an open end.

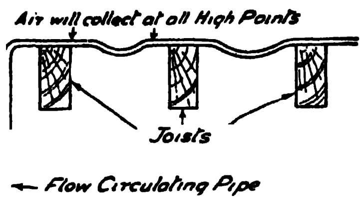
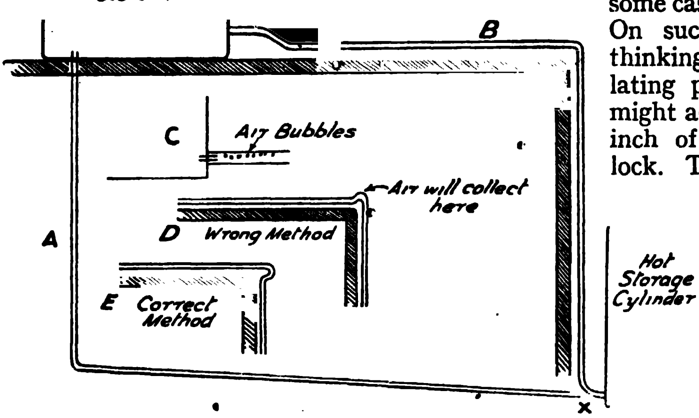


Fig. 5. Air lock caused by air collecting at high points when lead pipe sags between joists.

In this case, if a brass connexion a size smaller than the pipe had been inserted, as at C, Fig. 4, the top part of the pipe would be filled with air, which would reduce the flow.



HOT WATER SUPPLY: PROBLEMS. Fig. 4. Air lock in feed pipe: A, drop feed from bottom of cistern, sometimes recommended as better than position B; C, air collects in pipe where connexion used is smaller than pipe; D, air lock caused by pipe raised at corner: trouble avoided by method E.

Where a lead pipe has to be carried along a boarded surface and then turn down over a right-angle corner, it is obvious that such pipe could not possibly be bent closely to the angle. The plumber might unthinkingly raise the pipe before the drop, as at D (Fig. 4), and thus cause severe air lock. The proper method is as shown at E (Fig. 4).

So much trouble has arisen with side outgoes for feed pipes that some excellent authorities believe that the horizontal length should be one size larger than that for the vertical length. They also argue that, size for size, a feed pipe as shown at A (Fig. 4) gives a better flow than that shown in B. But the writer cannot agree that that is so. He has tried it out both ways repeatedly, and the vertical outgo showed no advantage whatever in the time taken to empty a cistern. The rate of discharge is governed by bore of pipe plus head of water minus frictional resistances. With these the same in each case it would seem that both pressure and flow at X (Fig. 4) are bound to be the same.

Unlevel Floors. In some ill-constructed houses circulation trouble has arisen because the plumber assumed that the upper floors would be level, whereas they had a pronounced inclination (in some cases as much as two inches). On such a floor the plumber, thinking he was giving his circulating pipes a rise of one inch, might actually be giving them one inch of fall, with resultant air lock. The moral is, "Always use a spirit level."

Many plumbers fail to realize that air lock always occurs at a high point of the pipe-line—not at a dip—and that a dip is as effective as an arch in causing air lock. This is shown clearly in Fig. 5. For this reason, when lead circulating pipes have to cross joists, the space between the joists must be "bridged" with boards to prevent sagging.

Vent and Supply Pipes. The writer has come across two cases—one thirty years ago and one within recent years—where more than one plumber of long experience had failed to solve a simple air lock trouble. The defect and the cure were the same in each instance, and are simply illustrated in Fig. 6.

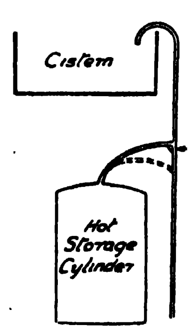


Fig. 6. Air lock due to arch in lead pipe (dotted), caused by slipping of vertical pipe from original position A.

The pipe leaving the crown of the stor-

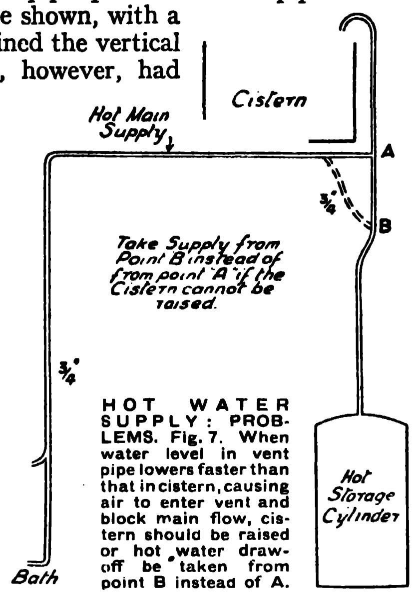
age cylinder was branched into a vertical pipe, the top part to act as a vent and the lower part as the main hot supply. As fixed originally the branch pipe presumably followed the solid line shown, with a definite rise to where it joined the vertical pipe. The vertical pipe, however, had slipped down until the branch took the line shown dotted, forming a trap for steam or air and stopping almost entirely the flow of water at the hot taps. When the pipe was raised to its original position there was no further trouble.

On one occasion the writer's opinion was asked about the fixing of such pipes, which had been a subject of argument amongst craftsmen. The inquirer stated that he himself always wiped three lugs on the vertical pipe; one just below the branch joint and another at some distance on either side, screwing the lugs to a running board.

Certainly a lug should be wiped on to the pipe just below the branch joint and screwed to maintain the pipe in position at the most vital point. But, above and below, the pipe should be secured with hard metal clips to keep it straight and yet allow expansion and contraction movements to take place without straining the pipe or loosening the fixing screws.

Cold Water From Hot Taps. This defect has occurred while the water in the storage cylinder was quite hot. The reason was that the expansion or vent pipe, turning over the cistern, was much longer than necessary. It had gradually fallen until the end was quite submerged. When a hot tap was opened the cold water was siphoned down the expansion pipe to the taps. Immediately the pipe end was raised, and shortened to prevent recurrence, there was no further trouble.

No Supply at Hot Taps. At the installation in a bungalow the users could draw no hot water. When a hot tap was opened, water ran for a few seconds and then the flow ceased altogether. This trouble has been experienced often in self-contained flats, but need not occur anywhere. The material part of the layout was as shown in Fig. 7. When the bath tap is opened fully the level of water in the vent pipe falls much more quickly than does that in the cistern—so quickly, in fact, that after a few seconds air is drawn through the vent pipe and effectively prevents hot water being drawn from the storage cylinder.



HOT WATER SUPPLY: PROBLEMS. Fig. 7. When water level in vent pipe lowers faster than that in cistern, causing air to enter vent and block main flow, cistern should be raised or hot water draw-off be taken from point B instead of A.

In a bungalow the best remedy is to raise the height of the cold storage cistern in the roof space, but this cannot be done in a self-contained flat. For this latter case two remedies are available. The first is to put in a feed pipe one size larger than the main hot draw-off, preferably with a trumpet-mouthed outgo, so that water will be replaced more quickly than it can be drawn. The second remedy is to take the main hot draw-off from a lower point on the vent pipe, as shown in dotted lines in Fig. 7.

Other methods are sometimes adopted, such as one-way valves on the vent pipe, but a vent pipe should be full bore through its entire length, with no obstruction whatever.

Noises in Boilers. Noises in back-boilers are generally caused through a boiler union protruding below the level of the boiler top, leaving an air pocket. A simple method of preventing such noises is to file a vee-shaped cut across the bottom end of the union, thus allowing the air to escape. It may be that the shape of the boiler itself leaves an air space which will cause such trouble. In that case the boiler should be drilled and tapped and a small branch tube taken from the highest point of the boiler into the flow pipe. *See* further under Boiler: (8).

The High Flow Connexion. The high flow cylinder connexion (Fig. 8) is now commonly adopted in preference to the older method, in which the flow connexion to the cylinder was made about 3 in. above the return

connexion. In the older method all the hot water coming up from the boiler through the flow pipe has to pass through the mass of cold water in the storage cylinder before going into "storage" at the crown, much of its heat being dissipated in the process.

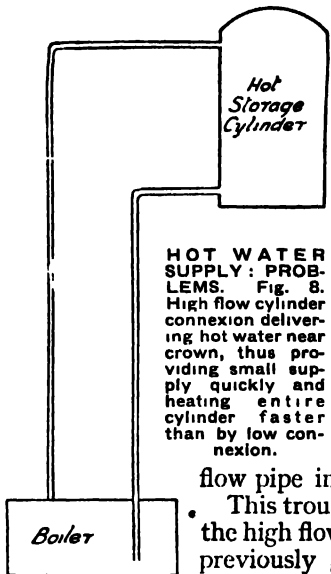
With the high flow connexion the hot water is delivered near the crown of the cylinder, thus giving a small hot supply much more quickly. Experiments have shown that this method also heats up the whole cylinder content more quickly than does the older one.

Cylinders with high flow connexions were made over forty years ago, but many plumbers refused to install them, which may seem strange in view of the advantages already stated.

It is accepted as a general principle that short circulations give the best results, and the installation shown in Fig. 8 is ideal in that respect. But in many of the large houses built half a century ago the bathroom and cylinder were at the opposite end of the house from the boiler, necessitating a long horizontal circulation.

In such cases the high flow connexion is not to be recommended: several instances have been encountered in which reversed circulation has occurred (*see* Fig. 9). Soon after the fire was lighted rumbling noises were heard and continued until all the water in the boiler and cylinder became of approximately the same temperature and a state of comparative equilibrium was reached. Then the circulation righted itself with a specially loud rumble.

The solution of this problem in one case was assisted by a chance remark of a tenant, viz. "this happens only when the water in the cylinder has remained hot or warm overnight while the water in the upstand of flow pipe, owing to its much smaller volume, has become quite cold."



HOT WATER SUPPLY: PROBLEMS. Fig. 8. High flow cylinder connexion delivering hot water near crown, thus providing small supply quickly and heating entire cylinder faster than by low connexion.

Taking a line through the crown of the cylinder and through the centre of the boiler, it will be seen that the flow column, which should be lighter than the return column of water, is under these conditions definitely the heavier of the two, and as water is heated in the boiler it takes the line of least resistance and flows up the "return" pipe.

The reversing circulation can be righted almost immediately by drawing water from the hot tap, the incoming cold and denser water from the feed pipe forcing water in boiler and flow pipe in the proper direction.

This trouble may be encountered, with the high flow connexion, in an installation previously giving complete satisfaction if the storage cylinder has subsequently been insulated. A probable cure is to insulate the upstand of the flow pipe.

Where long horizontal circulations are unavoidable, the writer suggests the adoption of so-called "lazy" pipe, which takes a short cut from the flow pipe direct into the expansion pipe (*see* Fig. 9*a*).

With this method, even if the water in the cylinder has remained hot overnight, and the flow column (including the "lazy" pipe) is colder and denser than the "return" column, the "lazy" pipe does not operate until the circulation has

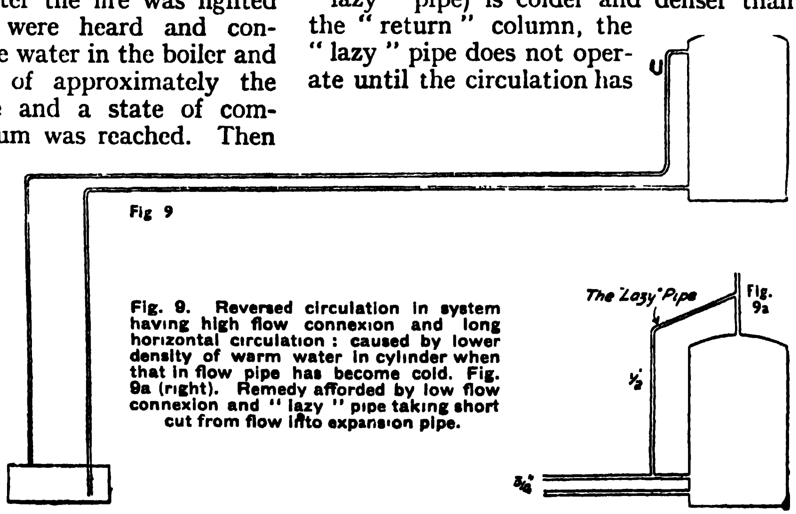


Fig. 9. Reversed circulation in system having high flow connexion and long horizontal circulation: caused by lower density of warm water in cylinder when that in flow pipe has become cold. Fig. 9a (right). Remedy afforded by low flow connexion and "lazy" pipe taking short cut from flow into expansion pipe.

been started normally via the low-flow connexion. Once that has started, the hot water from the boiler gradually works its way through the "lazy" pipe and gives the quick, small hot supply.

HOUSE. The requirements of the domestic house, as regards plumbing, roofwork, drainage, sanitation, hot water supply, heating and ventilation, are covered in all the principal articles or groups throughout this work. Flats, on account of associated special considerations, are discussed under their own heading. *See also* Building Construction. For details of domestic engineering and sanitation refer to classified entries in the Index at the end of Vol. 3.

HOUSING ACTS. The Housing Act, 1936, consolidates with minor amendments the provisions of a number of previous Acts which in the main it repeals. The Act is of importance to the sanitarian, inasmuch as, among other things, it defines "sanitary defects" which may render a house unfit for human habitation and may result in its demolition if incapable of being remedied. Further, a definite standard of requirements in regard to sanitary matters can be laid down in the by-laws which local authorities are empowered to make under the Act.

By-Laws, Including Sanitary By-Laws. Thus under Section 6 of the Act By-Laws have been made by the London County Council with respect to "houses which are occupied, or are of a type suitable for occupation, by persons of the working classes and let in lodgings or occupied by members of more than one family." These provide, among other things, for the provision of sinks or other efficient means of carrying off waste water from taps (13), while a duty is cast upon owners of lodging-houses to provide and maintain for the use of each family in the house, if possible on the story occupied by the family, water-closet accommodation and accommodation for washing clothes.

Under Section 6 of the Housing Act, 1936, Model By-Laws, Series No. XIII, have also been issued by the Ministry of Health with respect to houses which are occupied, or are of a type suitable for occupation, by persons of the working classes. In accordance with By-Law 3, every owner of a house must provide (*a*) closet accommodation and (*b*) a supply of water for domestic use, adequate and readily accessible to the occupier. By By-Law 4, every owner must: (i) keep in good repair all means of drainage; (ii) provide and maintain in connexion with every tap from which water may be drawn efficient means for carrying off any waste water from the tap; and (v) provide every closet with efficient means of ventilation directly into the external air, and, except where the closet is entered directly from the external air, with a window of an area of not less than 2 sq. ft., opening where practicable directly into the external air.

The Housing Act of 1936, apart from its by-law-making provisions, is of particular interest by reason of the powers conferred upon local authorities to deal with insanitary houses. Section 188 of the Act gives a definition of "sanitary defects," and among them is the absence of an adequate and readily accessible water supply or sanitary accommodation or of other conveniences.

Powers of Local Authorities. Local authorities are empowered under the Act to require the repair of an insanitary house (Section 9) or to order its demolition (Section 11). By Section 12 a closing order can be made as to part of a building. By Section 25 a local authority being satisfied that houses in an area in their district are, by reason of disrepair or sanitary defects (*see* above), unfit for human habitation, can declare that area to be a clearance area and apply the procedure contained in Part II of the Act. Briefly, after the local authority, as respects a clearance area, determine to order demolition of the buildings in the area they must make and submit to the Minister of Health an order (clearance order), ordering the demolition (Section 26) in the form prescribed by the Minister—Form No. 13 of the Housing Act [Forms] Regulations (S.R. & O., 1937, No. 78). Before submitting the order to the Minister the local authority must publish in the local press notice in the prescribed form stating that the order has been made, and also serve a notice (Form No. 14 of the 1937 Regulations) on owners, lessees and occupiers of the property affected. The order is then submitted to the Minister, and if no objection is made by those upon whom notice is served, he will confirm it. In

any other case the Minister must hold a public local inquiry before confirming the order and consider any objections not withdrawn (Third Schedule). When a clearance order has become operative, the land to which the order applies can be used for building purposes, or otherwise developed only in accordance with any restrictions and conditions the local authority may impose (Section 26 [5]).—*W. T. Creswell, K.C.*

H-PIECE. A hollow metal fitting designed to prevent stagnation in the flow of hot water, used on the secondary system of hot water supplies. A four-end piece is not unlike the capital H ; the three-end piece has a likeness to the small h. The four-end piece fitting is used at the ends of the double towel rail where it promotes inter-circulation between the rails, thus transforming the towel rail in principle to a hot water cylinder. To obtain a somewhat similar action the H-piece is sometimes used on low pressure heating systems where the "runs" are laid in three pipes, the two top pipes acting as the flow. A uniform heat is maintained by introducing H-pieces to connect the two upper pipes, the bottom pipe being the return.

The small h-piece is used in light copper tube installations. The secondary circulation is carried along below a range of lavatory bowls or to an isolated unit. The long leg of the h is fixed on the flow and the tail of the h forms the return.

HUMIDITY, ATMOSPHERIC. The humidity of air is the quantity of moisture in air in the form of aqueous vapour.

Absolute humidity is the actual quantity of water vapour present, usually expressed in grains of moisture per pound, or per cu. ft. of air. ***Relative humidity*** is the ratio between the quantity of moisture actually present and the maximum amount of moisture that the temperature of the air would enable it to contain. The ***dew point of air*** is the temperature corresponding to 100 per cent. relative humidity.

In a manner somewhat similar to that of an absorbent substance, air will take up moisture freely until it is saturated, its capacity for moisture increasing with temperature. For instance, air at 60° F. would be saturated by 77 grains of moisture per pound. In normal, comfortable surroundings, air at that temperature would contain about 46 grains/lb., corresponding to a relative humidity of

$$\frac{46}{77} \times 100 = \text{say, 60 per cent.}$$

If air in that condition were cooled, it would eventually reach a temperature at which 46 grains of moisture per pound would mean saturation. In this instance, that would be 45° F., which would be the dew point; any further lowering of temperature would cause the air to deposit some of the moisture in the form of dew.

Air Conditioning. The reason for artificial humidification of air will be seen in heating air at 40° F. and 60 per cent. relative humidity to a temperature of 60° F. The moisture present (absolute humidity) would be 21 grains/lb., which at the higher temperature would represent only 27 per cent. R/H. That would be much too "dry" for comfort, and would cause excessive dryness of skin and lips by too rapid evaporation of perspiration.—*J. W. Cowan, A.M.I.H.V.E.*

See Air Conditioning; Kata Thermometer.

HUMUS TANK. A chamber in which the suspended solids in the effluent from sewage filters are removed. In contact or percolating filters the putrescible matters are oxidized, and are purified by bacteria which live in the filter. The liquid leaving the filter contains waste matter from this biological life together with partly oxidized remnants of the original sewage solids. Unless land treatment is given to this liquid, or the stream into which it is discharged affords adequate dilution, these solids should be removed in a humus tank.

Design and Construction. A humus tank should be constructed of brickwork in cement mortar, faced internally with a cement rendering, or be built of good quality concrete. For small works a simple rectangular tank with a capacity equal to three or four hours of the flow in dry weather would be suitable. If possible the dry weather flow should be measured, and is approximately equal to the water consumption plus the ground water that leaks into the sewers.

In urban areas where the sewers have been well constructed the dry weather flow is usually about 20 to 25 gal. per person per day. Therefore if the population served is 200 the capacity of the humus tank would be $200 \times 20 \times \frac{4}{24} = 666$

gal., or 106 cu. ft. The length should be three or four times the width, and the depth should be three or four feet. Thus the tank would be about 3 ft. 6 in. wide, 10 ft. 6 in. long and 3 ft. deep at the outlet end. A scum board should be fitted near the outlet end of the tank to prevent scum being carried away with the effluent. To facilitate removal of humus or sludge the floor of the tank should be given a longitudinal fall of about 1 in 10 to the inlet end, where a plug or valve, with handwheel outside the tank, should be fitted.

Humus tanks with pyramidal bottoms are sometimes constructed, but are more costly. Humus or sludge should be removed every two or three days.—*W. H. Hillier, M.Eng., A.M.Inst.C.E.*

See Filter: (1); Sewage Treatment.

HYDRAULIC RAM. *See* Pumps and Rams.

HYDRAULICS & HYDROSTATICS FOR PLUMBER AND HEATING ENGINEER

By J. W. Cowan, A.M.I.H.V.E.

Here are given simple explanations of certain scientific facts which the plumber and the student of heating must know for the intelligent understanding of their work. Hydraulics in simple outline are first considered, Hydrostatics being the subject of the second section. See *also* Drains: (1), Section E; Head of Water; Heating; Pressure; Pipe Sizing; Water.

1. ELEMENTARY THEORY OF HYDRAULICS

Hydraulics is the science which treats of fluids in motion, especially the flow of water in pipes. Calculation of the flow of water through pipes and the determination of pipe sizes for specific duties have to a large extent been reduced to the use of formulae derived from experiment. At best, these are attempts to evaluate the resistances which tend to oppose the motion of the water, and it is doubtful whether calculated results are ever more than approximately correct. Only in precise calculations is numerical expression given to the roughness of the pipe wall, but the over-size bores of mild steel tubes, and the great difference in capacity between one commercial pipe size and the next combine to render this omission comparatively unimportant. Generally, the formulae relate to smooth-surface, true-to-size tubes, such as lead and copper, and the excess of actual over nominal bore of mild steel pipe is taken as compensation for the rougher surface in contact with water.

Head or Pressure. In hydraulics the governing factor is the head or pressure behind the moving column of water. This provides the motive energy of the movement, and may arise either from a head of water or from the propulsion of a pump. Other factors, such as size and length of pipe, roughness of surface, and changes in direction, combine to set up frictional resistance to the flow (*see* Friction). Hydraulic formulae endeavour to weigh these opposing forces one against the other and to assess the probable results in terms of outflow. This is sometimes stated as ***velocity in feet per second*** but for the ease of application, discharge is more usually calculated in ***gallons per minute*** (g.p.m.).

Box's Formula. Perhaps the best known hydraulic formula is that of Thos. Box, according to which:

$$H = \frac{G^2 \times L}{(3D)^5} \quad \text{and} \quad G = \sqrt{\frac{(3D)^5 \times H}{L}}$$

when, H = loss of head in feet of water;
G = discharge in g.p.m.;
D = diameter of pipe in inches;
L = length of pipe in yards.

In practice, however, the length of pipe and the available head of water are frequently determined by structural considerations, and leave only the size of pipe to be decided. By transposition of the above figures, it follows that:

$$D = \sqrt[5]{\frac{G^2 \times L}{H}} \div 3$$

the formula from which many discharge tables and graphs have been calculated. Practical applications of this formula in tabular form will be found in the article on Pipe Sizing.

Application to Pipe Sizing. Given that the length (L) and the head (H) have

been decided by the positions of taps and the height of the building, it remains only to estimate a probable discharge (G) to enable the formula to be used. Both "reasonable demand" and "simultaneous demand" are discussed more fully under the heading Pipe Sizing, but for this example it may be assumed that the reasonable requirements of a small suburban house in gallons of water per minute would be: bath 5, basin 2, and sink 3, a total of 10 g.p.m. If that supply were required in a cottage where the head above the taps was 10 ft., and length of pipe from storage tank to most distant tap was 45 ft., the values required would be:

H = 10 ft., G = 10 g.p.m., and L = 15 yd.
Thus,

$$D = \sqrt[5]{\frac{G^2 \times L}{H}} \div 3 = \sqrt[5]{\frac{100 \times 15}{10}} \div 3$$

$$\sqrt[5]{150} \div 3 = 2 \cdot 7 \div 3 = 0 \cdot 9 \text{ in. diameter.}$$

From this it would seem that a 1 in. diameter pipe would be ample to supply all three taps at once. It must be noted, however, that no allowance has been made for the resistance head (*see* Friction) of the bends, tees and valves, etc. It is necessary now to add the "*equivalent length*" *factor* for each obstruction to the measured length of 15 yd., and to check the calculation to ensure that a 1-in. pipe will be sufficient for this duty. Where elbows were to be used, this might mean an equivalent length of 24 ft. (8 1-in. elbows = 3 ft. each), and an addition of 8 yd. to the measured length of 15 yd. This would increase the length factor (L) to 23 yd., and the revised calculation would be:

$$D = \sqrt[5]{\frac{100 \times 23}{10}} \div 3 = \sqrt[5]{230} \div 3 = 3 \div 3 = 1 \text{ in. diameter}$$

showing that a 1-in. pipe would be only just large enough to meet a simultaneous demand at these three taps, without the margin seemingly provided by the earlier figure of 0·9 in. In calculating the size of a long, complicated run, it is advisable to increase the measured length of pipe by from 30 to 50 per cent. in allowance for the local resistance of fittings in the initial calculation, but this does not overcome the need to check the approximation against the total resistance head.

In practice, a pipe sizing table or chart is to be preferred to separate calculation of each pipe size, but before the tables can be used with safety it is necessary to understand the basic formulae from which they have been derived.

In problems which do not involve an outflow of water the calculations are similar except that *velocity of flow* takes the place of *discharge in gallons.* The velocity must then be such as to ensure that the requisite quantity of hot water in *pounds per hour* (lb./hr.) can pass freely to each point where heat is required. The same consideration must then be given to the motive energy available, and to the several forms of energy-consuming resistance to be encountered by the flow. Resistance head becomes of considerable moment when the total head available is, perhaps, only 1·5 in. or less of water gauge—12 in. w.g. (or 1 ft. of head) represents a maximum pressure of 0·433 lb. per sq. in.

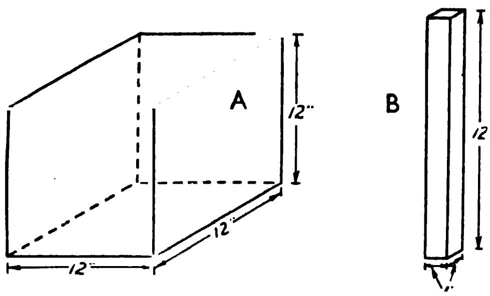
In Section E of the article Drains: (1) an account is given of the hydraulics of drainage with practical calculations.

2. SIMPLE OUTLINE OF HYDROSTATICS

Hydrostatics is the science which treats of the pressure and equilibrium of fluids, especially water, when at rest. The pressure exerted by a stationary body of water arises from the weight of the water and is known as static pressure. It is determined by the vertical height of the column, this being known as "head," and by the density or compactness of the water. For general calculations the standard weight of water is taken as 62·360 lb. per cu. ft., corresponding to a temperature of 62° F. This qualification is necessary because water expands and contracts with variation of temperature, and so becomes lighter or heavier, bulk for bulk, than a similar volume at a different temperature.

Water Exerts Pressure. It is of fundamental importance to note that a fluid at rest, whether liquid or gaseous, exerts pressure at right angles to any surface in contact with it, and that this thrust is exercised equally in all directions. It would be unreasonable to expect that the air pressure within an inflated ball

should be other than the same at any number of points on the spherical bladder. As will be seen, pressure due to a column of water acts in a similar manner against every part of the surface of the containing vessel. This analogy is not particularly apt, because the pressure of a gas arises



HYDROSTATICS. Fig. 1. Water pressure: A, 1 cu. ft. of water, exerting a pressure of 62·360 lb. on its base of 144 sq. in.; B, column of water 12 in. high exerting a pressure of ·433 lb. on its base of 1 sq. in.

from compression and a natural tendency to occupy a greater space; water is virtually incompressible and can only transmit pressure applied externally, or resulting from its own weight.

Pressure Due to Head. Fig. 1A represents a cubic foot of water weighing 62·360 lb. This weight is supported by the base, and it will be seen that the area of the base is 144 sq. in. (12 in × 12 in.). It follows that each square inch of base is supporting an equal share of the total weight and is, therefore, under a pressure of $\frac{62\cdot360}{144} = 0\cdot433$ lb. In other words, one foot of "head" or vertical height of water will exert a pressure of 0·433 lb. *per sq. in.*

Fig. 1B represents a column of water measuring 1 in. × 1 in. × 12 in. high, weighing 0·433 lb., and causing a pressure of 0·433 lb./sq. in. at its base. If four such columns were placed side by side, the total weight and pressure would be increased fourfold: 0·433 × 4 = 1·732 lb. If ten columns were so placed, the increase would be tenfold: 0·433 × 10 = 4·33 lb., but in both cases the bases would have undergone a proportionate increase, thus leaving the pressure in *lb./sq. in.* constant at 0·433 lb. *for 1 foot of vertical height or "head."* Now, assume that the four columns are built up vertically, one above the other, on the base occupied by a single column, and also that the ten columns are built up similiarly on another base. The total pressures would be 1·732 lb. and 4·33 lb. as before. On this occasion, however, the areas of the two bases would remain 1 sq. in., so that the pressures exerted by the columns would be 1·732 lb./sq. in. and 4·33 lb./sq. in., due, respectively, to 4 ft. and 10 ft. of "head"—or just 0·433 lb./sq. in. per foot of vertical height.

Fig. 2 shows two open-top tanks connected to a somewhat improbable arrangement of pipes; also a length of ¼ in. diameter pipe; all are full of water and all outlets plugged. The pressures at the points indicated by the alphabetical indices would be:

A and C = 21·65 lb/sq. B, G and H 17·32 lb. sq./in.
D and F = 12·99 lb./sq. in. E 8·66 lb./sq. in.; J = 25·98 lb./sq. in.

In each case the vertical height or head of water determines the pressure, irrespective of the size of tank or pipe, or length of pipe. The total pressures at these points would be calculated by multiplying the respective pressures per unit area by the areas of the bases or plugs (in square inches) in contact with

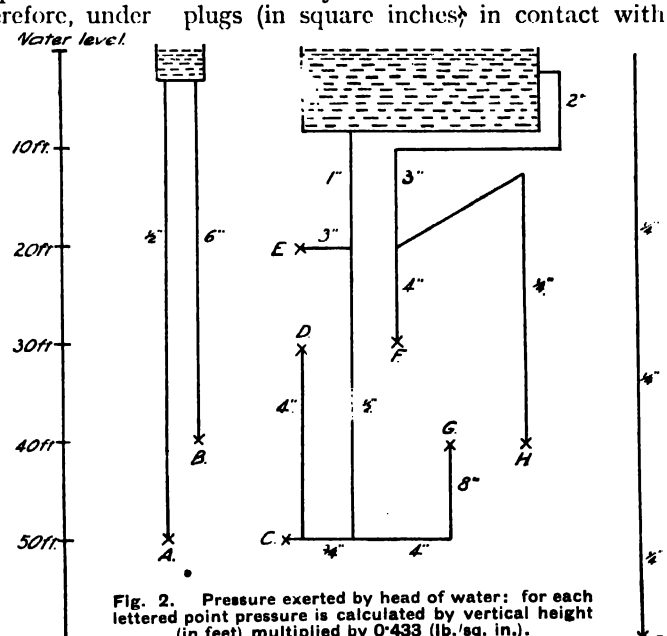
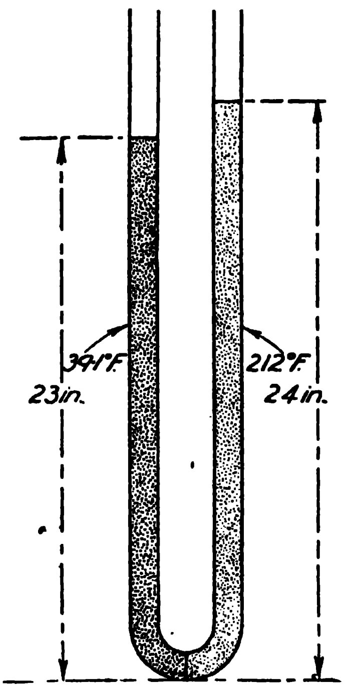


Fig. 2. Pressure exerted by head of water: for each lettered point pressure is calculated by vertical height (in feet) multiplied by 0·433 (lb./sq. in.).

water. For example, the area of a ½-in. pipe is 0·1963 sq. in., and that of a 6-in. pipe, 28·274 sq. in. The total pressures at points A and B in Fig. 2 are therefore:

$$A = 21{\cdot}65 \times 0{\cdot}1963 = 4{\cdot}25 \text{ lb.}$$
$$B = 17{\cdot}32 \times 28{\cdot}274 = 489{\cdot}7 \text{ lb.}$$

Static pressure arises from a natural tendency of water to "rise to its own level," as it does in both legs of an open-ended U-tube. When a plug or other obstruction prevents such a state of equilibrium, the obstruction is necessarily subjected to the pressure exerted by the difference in height between the opposing columns. The reservoir of a town supply and a domestic tap or ball valve may be regarded as the opposite ends of a U-tube. The tap or ball valve is always under the pressure caused by the difference in height: this may be expressed either as a pressure, say, 39 lb. per sq. in., or directly as a height, as 90 ft. head. The U-tube analogy is of great practical importance in central heating and water supply problems.



HYDROSTATICS. Fig. 3. Effect of difference in density: 24-in. column of water at 212°F. balancing 23-in. column of water at 39·1°F. because of the greater density (and therefore weight) of the colder water.

Effect of Difference in Density. So far these notes have dealt with cold water of equal density throughout. In hot water pipework a greater height of warm water is required to balance the pressure arising from a lesser height of cold water, because of the higher temperature and, therefore, lesser density of the warmer water. From the fact that water expands 1/23 of its volume at maximum density (39·1° F.) when heated to 212° F., it follows that a state of equilibrium with that temperature difference would require a difference in level of 1/23 of the height of the cold column. This seeming lack of balance is seen in Fig. 3, in which it is assumed that there is no intermixing of the hot and cold water.

In practice, the height of the cold leg (cold feed pipe) might be more nearly 23 ft., in which case water at 212° F. in the hot leg (flow and vent pipes) would stand at a height of 1 ft. instead of 1 in. above the level of the water in the cold tank. To ensure that vent pipes shall not discharge water even under excessive firing, the fraction 1/23 is taken as 1/24 (or as ½ in. per foot) and is doubled to give 1 in. per foot of height between tank and boiler as the safe height to which a vent pipe should extend above a cold feed or storage tank. (*See also* Hot Water.)

Transmission of Pressure. It should also be understood that water can transmit pressure, in addition to exerting that force by reason of weight. Fig. 4 shows three differently shaped vessels of equal base area. Under a similar head, the pressures on the bases would be equal. The volumes of water contained have no bearing upon the pressures exerted on the bases. In each case the pressure transmitted by head must be 0·433 lb. *per square inch of base per foot of vertical height*, without regard to volume or total weight of the water. It may be noted that the total pressures on the bases of the narrow-top vessels would exceed the total weight of the water. In the wide-top centre vessel some part of the weight of the water would be supported by the outward sloping sides, and the total pressure on the base would, therefore, be less than the total weight of the water.

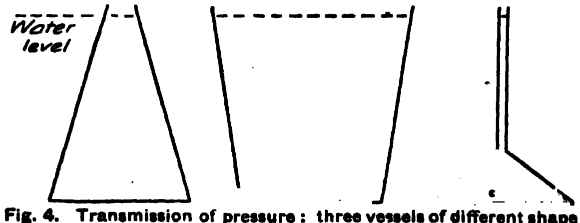


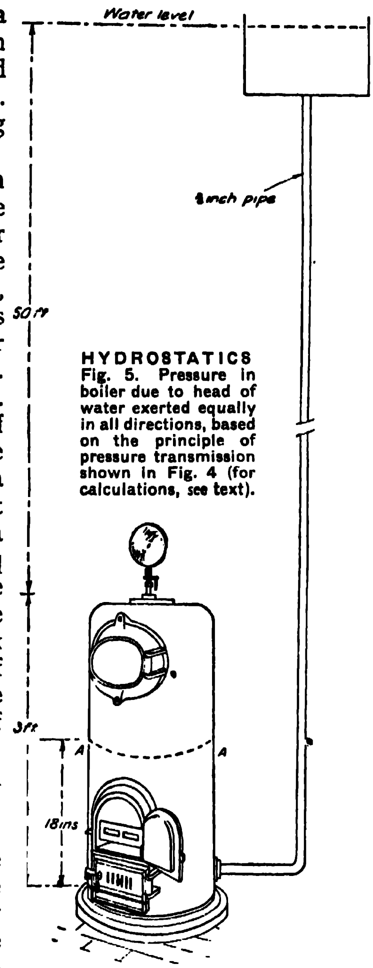
Fig. 4. Transmission of pressure: three vessels of different shape but having equal base areas and the same water level, so that the pressure on the base of each of the three vessels is the same (see Fig. 5 for application of the principle to a boiler).

Pressure in Boiler Due to Head of Water. The hydrostatic law, that pressure is exerted equally in all directions may be noted from

Fig. 5 which shows a boiler connected to an open-top tank situated at a height of 50 ft. above it, the whole being full of water.

If it is assumed that a dozen pressure gauges are connected to that number of tappings through the top plate of the boiler, each of the twelve gauges would necessarily register a pressure of 21·65 lb. per sq. in. (0·433 × 50). Similarly any number of gauges mounted on the shell of the boiler on a circumferential line at A—A would all give a reading of 22·3 lb. per sq in (0·433 × 51·5) because at that depth below the level of water in the tank each square inch of cylindrical shell would be subject to a thrust of 22·3 lb.

To calculate the total internal pressure within such a boiler, 22·3 lb. may be taken as the mean pressure per square inch, and multiplied by area of the interior of the boiler in square inches—*i.e.* the area of the cylindrical shell plus the areas of the top and bottom. Assuming a plain cylinder without firebox having internal dimensions of 36 in. high and 18 in. diameter, the total pressure would approximate 25 tons, 6 cwt., 37 lb., although the total weight of water supported by the base would not exceed 335 lb. It is for this reason that standard specifications prohibit the use of cast-iron boilers when the static head exceeds 120 ft. (52 lb. per sq. in.).



HYDROSTATICS Fig. 5. Pressure in boiler due to head of water exerted equally in all directions, based on the principle of pressure transmission shown in Fig. 4 (for calculations, see text).

Hydrostatic pressure is merely the "thrust" arising from the intensity of pressure within the liquid which, being unable to absorb the applied force, must transmit whatever load there may be equally to every part of the surfaces which support and enclose the liquid.

The Hydraulic Press. Fig. 6 shows the principle employed in a "Bramah" or hydraulic press, namely, the transmission of fluid pressure. Each cylinder is fitted with a watertight piston in contact with the water. If the area of the larger cylinder is 100 times greater than that of the smaller, it follows from the earlier paragraphs that a weight (or pressure applied by pump) of 1 lb. on the small piston would balance a weight of 100 lb. on the larger. In both cylinders the ***pressure in pounds per square inch*** would be the same, but there would necessarily be a hundredfold greater ***total pressure*** under the larger piston because of the hundredfold greater area. Similarly, a pressure of 1 lb. on the small piston would lift a weight of 99 lb. on the larger because of the transmission of equal fluid pressure (in lb. per sq. in.) between the cylinders.

Conversely, it would require a weight exceeding 100 lb. on the bigger piston to raise 1 lb. on the other. (Friction, etc., is neglected.) Because of the seeming absurdity of these claims this is called the ***hydrostatic paradox*** and is analogous to the "mechanical advantage"

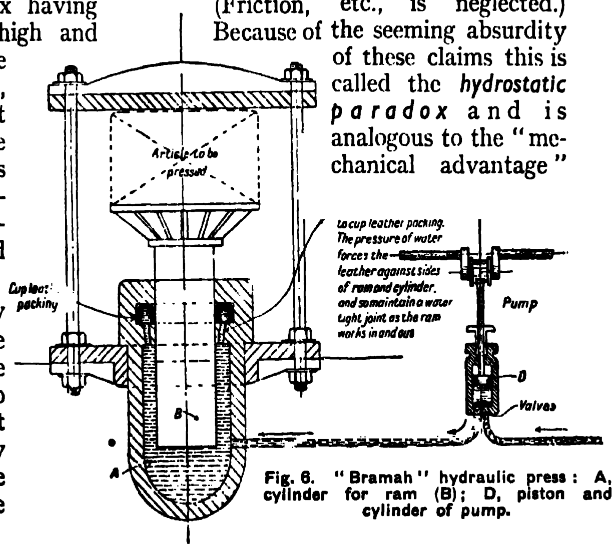
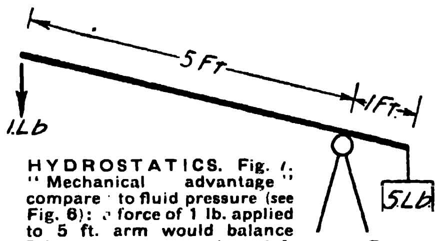


Fig. 6. "Bramah" hydraulic press: A, cylinder for ram (B); D, piston and cylinder of pump.

obtained by a lever, as shown in Fig. 7. The ratio of the area of the two cylinders determines the mechanical advantage of a hydraulic press ; that of a lever may be stated as : $\frac{\text{Length of arm of effort}}{\text{Length of arm of resistance.}}$

This is shown in the diagram as $\frac{5}{1}$, so that the advantage of a 72-in. lever in that position would be "5 times the applied force"—just as that of the cylinders seen in Fig. 6 is "$\times$100." It will be seen from Fig. 7 that a force of 50 lb., as might be applied by a normal man to the upper end of the lever, could lift a weight of 250 lb., and that by shortening the lower end of the lever to 6 in. (5 ft. 6 in. to 6 in. = 11) the same pressure would raise 550 lb. It is this principle that is employed when the "purchase" of a pipe wrench is increased by using a length of mild steel pipe to extend the handle—and frequently, to break the wrench !



HYDROSTATICS. Fig. 7. "Mechanical advantage" compare to fluid pressure (see Fig. 6): a force of 1 lb. applied to 5 ft. arm would balance 5 lb. weight attached to 1 ft. arm. Force x lever arm, and resistance x lever are the same on both sides of fulcrum.

Returning to the hydraulic press, it will be seen that by suitable adjustment of the relative areas of the cylinders the multiplication of the applied force could be increased to astronomical proportions. In moderate figures, a small cylinder of $\frac{1}{4}$ in. diameter coupled to a large one measuring 36 in. across would provide a mechanical advantage of 20,736 times the applied force, so that 1 oz. would balance a load of 11 cwt. 64 lb. It would be necessary, of course, as with the boiler in Fig. 5, to ensure that the walls of the cylinders could withstand the enormous total pressure, a fact which in some degree limits the practical application of this tempting source of power.

It should be noted that, whatever the gain in pressure, there is no corresponding multiplication of the height of travel of the opposing pistons. For instance, referring again to Fig. 6, if the smaller piston is forced down 1 in., only 1 cu. in. of water will be displaced and forced into the large cylinder. This volume spread over a hundredfold greater area can only raise the large piston 1/100 of the travel of the small piston, namely 1/100 in. In practice, an arrangement of check valves similar to those of a pump would prevent water from leaving the large cylinder, and the lever operating the small piston would be raised and lowered as often as was necessary to pump sufficient water under the large piston or "ram" to give the desired lift.

Hydraulic Jack. That is exactly what happens within the casing of a hydraulic jack. Water is pumped from a cistern under the "table" to the bottom of the casing and under the "ram" supporting the table; both ram and table rise in proportion to the quantity of water displaced by the plunger. In a small jack the diameters of the plunger and ram might be 1 in. and 5 in., providing a ratio of 25 to 1. To this would be added the mechanical advantage of the ratio of the travels of the lever handle and pump plunger.

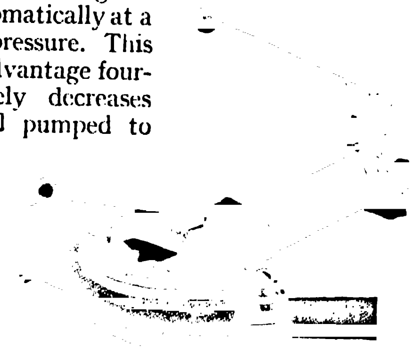
Assuming this to be 18 to 1, the combined advantages of ram and lever would be 450 (25 $\times$ 18). With a normal pressure of 50 lb. on the handle, it will be seen that by operating the lever a man could exert a theoretical lifting pressure of fully 10 tons : (450 $\times$ 50 = 22,500 lb.). Friction might reduce the actual efficiency to perhaps 80 per cent. of the theoretical, or to just over 8 tons ; but only a very slight adjustment of these ratios would be necessary to provide an actual lifting capacity of 10 tons.

Larger jacks used for baling scrap tinplate, wastepaper and cotton, etc., sometimes exceed 100 tons capacity from a pressure of perhaps 100 lb. on the handle, a mechanical advantage of 2,240, but that size might have more than one ram under the table. The smaller portable jacks (using oil instead of water) used in garages commonly range from 2 to 5 tons.

Fig 8 shows the "Staffa" hydraulic pipe bending machine which combines a lever advantage or "purchase" of 18 to 1 with a 2-stage hydraulic system to produce a total mechanical and hydraulic advantage of $\times$ 288 (i.e. 288 to 1). The cross sectional area of the horizontal ram compares with the combined areas of two lever-operated pistons of the low pressure stage as 4 to 1, and with that of the smaller piston alone of the high pressure stage as 16 to 1. These ratios

together with the lever produce an effective advantage of $\times 72$ (18×4) during low pressure, and $\times 288$ (18×16) in the high pressure stage. The larger of the two pistons cuts out automatically at a predetermined internal pressure. This increases the hydraulic advantage fourfold and proportionately decreases both the volume of oil pumped to the ram cylinder, and the rate of forward travel of the ram.

Hydraulic Brakes. A further application of this principle is seen in the hydraulic brakes of a motor-car, in several of which the liquid used is composed largely of glycerine and water. In these, instead of increasing the area of the ram, it is more usual to provide a greater number of rams or pistons in what would otherwise be the large cylinder.



HYDROSTATICS. Fig. 8. "Staffa" hydraulic pipe bending machine providing mechanical advantage of $\times$ 288; a normal load of 25 lb. on lever exerts a load of 7,200 lb. on horizontal ram. *Commercial Structures, Ltd.*

In the case of the "Lockheed" brake, one plunger, about 1 in. diameter, in a master cylinder is depressed by the brake pedal, and is in direct hydraulic communication with four wheel cylinders (inside the brake drums) each containing two pistons or rams of approximately the same size, which operate the brake shoes.

Bearing in mind the exertion of an equal pressure in all directions from Fig. 5, these eight pistons must exert a total pressure of eight times that applied to the plunger. To this ratio of 8 to 1 must be added the leverage of the pedal lever, probably 5 to 1. This represents a mechanical advantage of 40 (8×5). Assuming a normal pressure of 100 lb. on the pedal, the pressure on four wheels so braked would be 4,000 lb. A maximum emergency load of perhaps 150 lb. on the pedal would increase the retarding force by 50 per cent. to 6,000 lb.

Hydraulic presses are gradually supplanting the steam hammer in the production of heavy forgings, and hydraulic machinery is used extensively for heavy cranes, hoists and capstans, etc., and for stamping and riveting. These larger units are not, of course, hand operated. The control lever merely opens a valve which connects the mechanism with a high pressure water supply from a pressure intensifier which, in turn, may be fed with high pressure water from a hydraulic main. In large industrial towns mains water is available for industry at pressures up to 1,600 lb. per sq. in. By these means hydraulic forging presses up to 4,000 tons capacity are very commonly employed, and considerably heavier presses are in everyday use for a variety of purposes.

HYDROCARBONS.

Chemical compounds containing hydrogen and carbon only. For industrial purposes the chief methods of obtaining hydrocarbons are the destructive or dry distillation of certain organic substances, especially coal and petroleum, but they occur also in other sources such as natural gas, turpentine, and some essential oils. The hydrocarbons are of fundamental importance in the study of organic chemistry and form the basis or main constituents of an enormous number of substances used in industry and medicine. In the fuels—solid, oil, and gaseous—they are the predominating compounds. (*See* the Table *in page* 596.) All hydrocarbons have certain characteristics in common; they are combustible, neutral, and may be decomposed into their constituent elements by the application of varying degrees of heat.

In theory the hydrocarbons are infinite in number because of the way by which the hydrogen and carbon atoms combine, and a great many of these combinations are known. They are classified in the first place by the arrangement of their carbon atoms and may be in the form of gases, liquids, or solids.

The simplest of the hydrocarbons are the gases: for example, methane (CH_4) ethylene (C_2H_4), ethane (C_2H_6), and acetylene (C_2H_2). Ethylene and methane are constituents of natural gas, and methane of firedamp.

In the group of hydrocarbons to which methane and ethane belong, known as the "paraffins," are also found certain liquids and solids. The crude oil obtained in great quantities from the United States, Galicia, Persia, Mesopotamia, and other places is

for the most part a mixture of these hydrocarbons. When distilled they produce petroleum, naphtha, and many oils used for fuel, illumination, and lubrication: while further refining of the residue provides vaseline, paraffin wax, and many chemicals of great value. An important liquid hydrocarbon not belonging to the paraffin series is benzene (C_6H_6), the "parent hydrocarbon" of the so-called "aromatic group."

Solid hydrocarbons are found in coal and some in coke, although coke is largely composed of separated carbon, the volatiles having been driven off during distillation. During combustion the hydrogen present combines with oxygen, giving off heat and forming water, while the carbon forms carbon monoxide (CO) or carbon dioxide (CO_2). For fuel purposes

Hydrocarbons in Fuels

Fuel	Carbon	Volatiles	Hydrogen (H) and Methane (CH_4)
Anthracite	85%–90%	3%–8%	3·5%–3·9% (H)
Semi-anthracite ..	About 78%	About 15%	About 4%
Bituminous coal ..	50%–70%	20%–40%	About 5% (H)
Semi - bituminous coal	About 65%	16%–26%	About 5% (H)
Peat and lignite ..	50%–70%	About 50%	5%–7% (H)
Coke	75%–85%	—	—
Oil	85%	—	10%–15% (H)
Coal Gas	—	4%	40%–50% (H); 25%–35% (CH_4)

the carbon content of the coal is of chief importance, and as coal becomes more mature—as it approaches anthracite in form—the carbon percentage increases and the hydrogen percentage decreases.

As the coal burns, some of the volatile hydrocarbons are "consumed" and some are given off as smoke. The presence of smoke therefore indicates that there are incombustible gases present or that the carbon content of the coal has been incompletely used up. In the best anthracite and under satisfactory conditions all the carbon combines with oxygen, so that fumes of carbon monoxide and carbon dioxide are given off, but there is no smoke.

Since coke is largely composed of carbon (practically all the hydrogen and other gases in the original coal having been driven off during distillation), it also burns without smoke.—*E. V. Penn, M.A.*

See Fuel.

HYDROGEN (H). A colourless, odourless, non-poisonous gas. Owing to the readiness of hydrogen to combine with other substances the gas often contains impurities which give it an odour and may make it unhealthy to plants and animals. It is slightly soluble in water and somewhat more so in alcohol. Hydrogen is the lightest of all the gases, having a density of 0·0000895682, and when related to air (air=1) its specific gravity is ·069 at 32° F. and under atmospheric pressure. In the calculation of the specific gravities of various gases hydrogen is sometimes taken as 1·00, since it is the lightest (*see* Density). At a very low temperature and under moderate pressure it can be liquefied.

Hydrogen will not support combustion, but it burns readily with a very hot, pale blue, non-luminous flame. When in contact with air or oxygen hydrogen gas explodes readily on account of the rapidity with which it combines, especially if the volume of oxygen present is one-half that of the hydrogen.

In general hydrogen has many of the same properties as the metals and combines with the same elements, forming acids. It combines directly with most non-metals and with a number of metals, and during the process of combination with oxygen, fluorine, and bromine much heat is given off. Combined with oxygen, hydrogen forms water (H_2O) and hydrogen peroxide (H_2O_2), the latter being a bleaching agent and an antiseptic. Combined with nitrogen, hydrogen forms ammonia (NH_3); with chlorine, hydrochloric acid (HCl). A compound of hydrogen, hydrogen cyanide or prussic acid gas, is used for fumigation to kill vermin. By far the most important group of hydrogen compounds, however, are the hydrocarbons (*which see*), including solid, liquid, and gaseous fuels. *See* Acid; Hydrocarbons.

HYGROSTAT. Apparatus for the automatic control of humidity conditions in a building. As explained under the heading Air Conditioning, comfortable conditions depend a great deal upon the degree of humidity of the atmosphere, and the apparatus in question is devised to enable

those conditions to be controlled. The hygrostat works on the compressed air principle. A hygroscopic (moisture-indicating) element in the mechanism acts upon an air-leak valve in the control line and thus alters the position of a valve or damper in the air line.

I.E.E. REGULATIONS. All electrical installations in this country must comply with certain regulations made by various authorities, the object of which is to protect life and property. The earliest regulations of this kind were issued by the Board of Trade, but these have been superseded by those issued by other authorities, which between them cover the whole field of electrical work, from factory to mine. The regulations issued by the various authorities overlap as little as possible.

The regulations which cover the wiring of every type of dwelling house, business premises, public buildings and factory are issued by The Institution of Electrical Engineers under the title of "Regulations for the Electrical Equipment of Buildings" (obtainable from the offices of The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2, price 3s. 9d. post free). These are commonly referred to as the "I.E.E. Regs." or the "Wiring Regs."

Unlike most of the other regulations referred to, they have no statutory authority (i.e. they are not enforceable by law). But, nevertheless, they have considerable force, because, where "compliance with the Regulations which are current for the time being and which have been approved by the Minister of Fuel and Power can be proved in relation to a consumer's installation, that installation is deemed to fulfil the requirements of Regulations 25, 27, 28, 29 and 31 of the Electricity Supply Regulations, 1937." On the other hand, a supply authority (e.g. Area Board of the British Electricity Authority) may refuse to connect up an installation unless it complies with the Regulations. Moreover, many fire insurance companies insist on installations being in accordance with the Regulations as a condition of their policies.

The current (1952) edition is the 12th, published May, 1951. In the preparation of this edition, the Regulations as a whole were completely reviewed and recast, though the 1946 Supplement and Revised Section 8 have been incorporated with little change.

Two of the most far-reaching of the changes introduced by the 1946 Supplement were

(1) the sanctioning of the *ring main* for use in domestic installations in conjunction with 13-amp. socket outlets and fused plugs. In a ring main both ends of one conductor are connected to the same fuse terminal, and both of the other to the neutral link, so that the circuit is fed from both ends (*see* Reg. 201 (C), quoted in page 597A).

(2) Single-pole fusing, which forbids a fuse, or non-linked switch or circuit-breaker being inserted in a neutral, middle wire or common return conductor connected permanently to earth.

The Codes of Practice issued by the British Standards Institution are supplementary to the Regulations, and select one from a number of approved methods and recommend it as the preferred practice.

The main body of the Regulations is divided into 14 Sections, under the following headings:

Section 1.—The Control and Distribution of Supply.

Section 2.—The Arrangement of Final Sub-Circuits, and application of Diversity thereto.

Section 3.—The Installing of Conductors and Cables (General).

Section 4.—The Installation of Conductors and Cables (Methods of Wiring).

Section 5.—Temporary Installations.

Section 6.—The Installing of Accessories and Lighting Fittings.

Section 7.—The Installing of Current-using Appliances (including Rotating Electrical Machines).

Section 8.—The Installing of Electric Discharge Lamps (General).

Section 9.—The Installing of Electric Discharge Lamps (High Voltage).

Section 10.—Earthing.

Section 11.—The Testing of Installations.

Section 12.—The Installing of Private Generating Plant and Secondary Batteries.

Section 13. Requirements in regard to the Design and Construction of Electrical Apparatus (including Cables).

In addition there are four appendices:

Appendix 1. List of British Standards referred to in the Regulations.

Appendix 2. British Standard Graphical Symbols for Interior Electrical Installations.

Appendix 3. Correction Factors for Current Ratings for Single Core Cables.

Appendix 4 Regulations for Earthing to Water Mains.

To illustrate the nature of the Regulations, extracts are given from Sections 2 and 4.

Section 2. The Arrangement of Final Sub-Circuits

REGULATION 201. (A) Every final sub-circuit shall be connected to a separate way in a distribution fuseboard, provided that where there is only one such sub-circuit it may be directly connected to the main switchgear.

NOTE.—The use of a fuse in a plug or in a socket-outlet adaptor does not obviate the necessity of complying with Regulation 201 (A).

(B) A final sub-circuit having a rated capacity not exceeding 15 amperes may supply an unlimited number of points provided that :—

(i) the aggregate rating of the points does not exceed the current rating of the cable ;

(ii) in installations in private houses or residential flats there shall be at least one final sub-circuit for lighting, apart from socket-outlets, for each 1,000 sq. ft. of floor area, or part thereof ; and

(iii) the protection of flexible cords connected to the circuit complies with Regulation 202.

NOTE 1.—Regulations 506 and 807 contain special requirements for final sub-circuits in temporary installations and electric-discharge-lamp installations respectively.

NOTE 2.—In the interests of good planning, undue use should not be made of the provision that an unlimited number of points may be supplied by a single final sub-circuit.

(C) A final sub-circuit having a rated capacity exceeding 15 amperes shall not supply more than one point except as specifically permitted in the following exemptions (i) to (iv). These exemptions apply to installations in private houses or residential flats and to other installations where the application of a diversity factor can be justified, and in which all connexion of appliances to the circuits is either by means of fused plugs, or in accordance with clause (D) below. The application of these exemptions is restricted to the circuits and conditions described therein.

Exemptions :—(i) A final sub-circuit having conductors of not less than 0·0045 sq. in. cross-sectional area (7/·029 in.) or (0·003 sq. in. in the case of mineral-insulated metal-sheathed cable) and protected by a fuse having a current rating not exceeding 20 amperes may serve two socket-outlets each of 13-ampere rating.

(ii) A final sub-circuit having conductors of not less than 0·007 sq. in. cross-sectional area (7/·036 in.) (or 0·0045 sq. in. in the case of mineral-insulated metal-sheathed cable) and protected by a fuse having a current rating not exceeding 30 amperes may serve not more than six socket-outlets each of 13-ampere rating.

(iii) A final sub-circuit having conductors of not less than 0·0045 sq. in. cross-sectional area (7/·029 in.) (or 0·003 sq. in. in the case of mineral-insulated metal-sheathed cables) in the form of a ring both ends of which are brought into the terminal of a fuse having a rating not exceeding 30 amperes may serve not more than ten socket-outlets of 13-ampere rating; provided that in small houses or residential flats having a floor area not exceeding 1,000 sq. ft. the number of such socket-outlets served by such a ring circuit shall not be restricted.

(iv) It is permissible to take spurs from such a ring circuit as is described in (iii) above to outlying socket-outlets without intermediate fusing, provided that the branch conductors are not of smaller cross-sectional area than those forming the ring, that each spur does not serve more than two such socket-outlets, that the aggregate number of socket-outlets served by spurs from any individual ring-circuit does not exceed the number served directly by the ring-circuit and that the maximum number of socket-outlets served by any such ring-circuit and associated spurs together does not exceed that permitted in (iii) above.

(D) Fixed appliances may be fed from any of the sub-circuits permitted under the exemptions (i) to (iv) in clause (C) above, provided they are fed through fuses of appropriate current-rating mounted adjacent to the appliance, and that the sum of the ratings of all such appliances fed from a single final sub-circuit does not exceed 15 amperes. Where the number of socket-outlets permissible under the exemptions is limited, for every fixed appliance so connected the permissible number shall be diminished by one.

Section 4. Installing of Conductors and Cables

Tough-rubber—or P.V.C.—sheathed cables

REGULATION 404. Vulcanized-rubber- or p.v.c.-insulated cables with tough-rubber or p.v.c. sheathing complying with the requirements of Regulation 1306 may be used without further protection of casing or conduit, provided that the requirements of the following clauses (A) to (J) are complied with :—

(A) Where the cables are installed in a situation in which they may be exposed to direct sunlight they shall, if tough-rubber-sheathed, be provided with a special protective covering. If this protective covering is incorporated in the cable during manufacture it shall be in the form of a braid, but if applied subsequently it shall be a treated tape.

NOTE.—For the purposes of clause (A), sunlight which has passed through ordinary window-glass is deemed not to be direct sunlight.

(B) The cables shall be prevented by spacing, insulation, or other means, from coming into contact, under any conditions of service, with gas pipes or non-earthed metalwork other than metal cleats, saddles, etc., used to support the cable.

(C) Where the cables are liable to suffer mechanical damage they shall be adequately protected in relation to the nature of their sheath.

(D) The cables shall be secured by cleats, saddles or clamps (other than driven staples) or, subject to compliance with clause (C) above, may be embedded in plaster or alternatively may incorporate or be continuously bound up with a properly-suspended catenary wire. The insulators, cleats, saddles, and clamps shall have smooth or rounded edges that will not indent or damage the cables, and they shall be so designed and arranged as to prevent the

fixing screws or nails from damaging the insulation and protective coverings of the cables.

NOTE.—Tough-rubber-sheathed cables embedded in plaster are ordinarily deemed not to be subject to mechanical damage, but protection may be necessary in particular instances. Attention is drawn to the possibility of deleterious action on the tough-rubber sheath as a result of contact, in damp situations, with lime and certain cements and sprays.

(E) The spacings of the insulators, cleats, saddles, or clamps, where the cables are installed in such positions that they are likely to be disturbed, shall not exceed those specified in Regulation 403 (D) for metal-sheathed cables, unless the cables are supported throughout their length by properly-suspended catenary wires.

(F) Where the cables are installed in such positions that they are unlikely to be disturbed (e.g. under floors or within partitions), greater distances between the points of support are permissible than those specified in clause (E) above, but such distances shall not exceed 3 ft. In addition, the cables, where vertical, shall be gripped firmly at the supports, and where, owing to a change of direction, there is likely to be excessive pressure on any part of the cable, the cable shall be brought over a rounded support of a radius not less than six times the overall diameter of the cable [*see* Regulation 315 (E) for the bending of cables]. Cables run parallel to joists shall be attached to the sides of the joists.

(G) In damp situations and wherever exposed to the weather the cleats, saddles, and clamps, referred to in clause (D) above, together with the screws or nails used for fixing, shall be of non-rusting material

(H) Where the cable passes through floors, walls, partitions, ceilings, etc., the holes shall be made good with suitable cement or similar incombustible material to the full thickness of the material of the floors, walls, etc., and space through which fire might spread shall not be left around the cable; and where the cable passes through structural steelwork or ironwork every hole shall be so bushed as to prevent abrasion of the cable. Where cables are installed under floors, they shall be mounted on the sides of joists or in such other positions as are not liable to damage due to contact with the floorboards or floorboard fixings. Where the cables are sunk into the floor joists, the floorboards shall be fixed with removable screws.

(I) Every connexion between the conductors of cables shall be made in a joint box of ample capacity and complying with B.S. 816, and the box shall contain all parts of the cable from which the protective sheath has been removed.

(J) Except as specifically exempted below, where cables terminate at, or are looped into, an accessory or lighting fitting, a box shall be provided into which the protective sheath shall be brought in such a manner that all parts of the cable from which the protective sheath has been removed are enclosed within the box, accessory or lighting fitting.

Exemption.—Where a cable is run on the surface, the box called for above may be omitted provided that the protective sheath is brought into the accessory or lighting fitting or into a recess lined with incombustible material, or, where the surroundings are of in-combustible material, into a recess formed of or lined with hard wood such as beech, oak (English), teak or mahogany.

Conduits

REGULATION 405. Any type of cable which complies with Regulation 1306 (i), (ii), (iii), or (iv), other than the high-voltage cables specified in Regulation 907 for high-voltage electric discharge lamps, may be enclosed in conduit, provided that the requirements of the following clauses (A) to (P) are complied with:

(A) The conduits for each circuit shall be erected complete before any cable is drawn in.

NOTE.—Attention is drawn to the desirability of inspection boxes, draw boxes, etc., being accessible throughout the life of the installation for such purposes as the withdrawal of existing cables or the installing of additional cables.

(B) Metallic conduit shall be prevented by spacing, insulation or other means from coming into contact with (i) the wires, cables or sheath of any wiring system operating at extra-low voltage or of any system not installed in accordance with the requirements of these Regulations; (ii) the metal pipes of other services, e.g. gas or water. Where the separation called for above is not practicable, the conduit shall be bonded to the metal sheath and/or pipework of other services, with which it may come into contact, in such a manner as to prevent the occurrence of a voltage difference at such point of contact.

NOTE 1.—The bonding of the sheath of cables or conduit to other services may require the permission of the authorities responsible for those services.

NOTE 2.—Attention is drawn to the requirements of the Factories (Testing of Aircraft Engines, Carburettors and Other Accessories) Order, 1944.*

(C) Where conduits are liable to mechanical damage they shall be adequately protected.

(D) The maximum number of 250-volt-grade, vulcanized-rubber-insulated braided cables, or p.v.c.-insulated, braided or unbraided cables, run in one conduit shall be such that it permits of easy drawing-in, and in no circumstances shall be greater than the maximum set out in Table 22 for the particular size of conduit. For types of cables having larger overall diameters than those shown in column 3 of Table 22, appropriate reduction shall be made in the number of cables drawn into the conduits (*see* Table 23 for 660-volt grade, vulcanized-rubber-insulated, braided cables). Where necessary, arrangements shall be made to obviate the drawing of cables round more than two 90° bends, of a radius not less than that of the British Standard factory-made normal bend, or their equivalent.

(E) The radius of any conduit bend shall be such as to fulfil the requirements of Regulations 315 (E) and (F) for the bending of cable and, furthermore the inner radius of the bend shall not be less than 2½ times the outside diameter of the conduit; and elbows or tees other than those of the inspection type shall not be used, except at the ends of conduits immediately behind accessories or lighting fittings.

(F) Except as specifically exempted below, boxes shall be provided at every outlet position and such boxes shall be of metal where metal conduits are used.

* Obtainable from H.M. Stationery Office under reference S.R. and O. 1944, No. 495.

Exemption.—Where a conduit is run on the surface, a box need not be provided at any terminal position provided that the conduit is brought into an accessory or lighting fitting, or into a recess lined with incombustible material, or, where the surroundings are of incombustible material, into a recess formed of or lined with hard wood such as beech, oak (English), teak or mahogany.

(G) Every outlet for a cable from a conduit shall be bushed or so finished as to prevent abrasion of the cables emerging therefrom.

(H) Where the conduit passes through floors, walls, partitions, ceilings, etc., the hole shall be made good with cement or similar incombustible material to the full thickness of the material of the floor, wall, partition, or ceiling, and space through which fire might spread shall not be left around the conduit. Where conduits are sunk into the floor joists, the floorboards shall be fixed with removable screws.

(I) Substantial boxes of ample capacity complying with the appropriate British Standard shall be provided at every point where cable connexions have to be made. These boxes shall be of metal except that, where non-metallic conduits are used, the boxes may, if desired, be of non-absorbent, non-inflammable material other than metal.

(J) In damp situations and wherever exposed to the weather, the saddles and fixings used for securing the conduits shall be of non-rusting material or finish; and the conduits shall be watertight and, if of steel, shall be of heavy gauge and screw-jointed.

Note.—Conduit buried in plaster is in ordinary circumstances deemed not to be in a damp situation.

Attention is drawn to the possibility of corrosion, in damp situations of:—

(i) Metal conduits and ducts, and other metal parts, by certain materials containing magnesium chloride which are used in the construction of floorings and dadoes.

(ii) Steel conduits and ducts where plaster undercoats are contaminated with corrosive salts.

(*See* British Standard Code of Practice CP 211 "Internal Plastering," pp. 43 and 97.)

(K) If of metal, the conduits shall be earthed in accordance with the requirements of Section 10, and shall be mechanically and electrically continuous across all joints, so that the electrical impedance of the conduit, together with the impedance of the earthing lead, measured from the connexion with the earth electrode to any other position in the completed installation, shall not exceed 1 ohm.

Note.—Plain slip sockets do not comply with this condition, and some form of screwed or grip joint which will give ample and permanent electrical conductance and mechanical rigidity throughout is necessary.

(L) Inspection and draw-in boxes for use with metal conduits shall be in rigid electrical and mechanical connexion with the conduits.

Note.—Plain slip sockets do not comply with this condition, and some form of screwed or grip joint which will give ample and permanent electrical conductance and mechanical rigidity throughout is necessary.

(M) Vulcanized-rubber-insulated cables shall not be used without suitable protection in situations where they are likely to be permanently exposed to the risk of deterioration due to contact with rust.

(N) Cables installed in metal conduits shall always be so bunched that the outgoing and return cables are drawn into the same conduit.

(O) In the absence of statutory or other special regulations requiring the separation of the wiring of a.c. and d.c. systems, cables connected to one system may be run in a conduit with cables connected to the other system.

(P) Where flexible metallic tubing is connected to metal conduit, the adaptors attaching the tubing to the conduit shall be of a type suitable for connexion to the separate earth-continuity conductor required by Regulation 1003.

IMMERSION HEATER: TYPES & INSTALLATION

By L. C. C. Rayner, A.I.E.C.

In the first Section of this article Mr. Rayner describes the types of Electric Immersion Heater and deals with such matters as loading, rating and the reduction of heat losses. Notes are given on thermostatic control, and running costs. In the second Section the installation and fixing of immersion heaters is explained, with many practical hints and data. See Thermal Storage.

A. TYPES, RATINGS & CHARACTERISTICS

Electrical apparatus for water heating is discussed in this work under the headings Immersion Heater (the present article), and Thermal Storage Heaters. The general principles of hot water supply are explained under the heading Hot Water Supply: (1).

The immersion heater is a device for heating water electrically. Basically it is made of spirals or loops of wire drawn from metal having a high resistance, such as nickel-chrome. The flow of an electric current through the wire causes it to become hot, and if the wire is protected by a casing or sheath and immersed in water, the water in turn becomes heated. Modifications are made to this elementary heater in practice. The wire must be insulated from the sheath to prevent electrolysis of the water and to prevent any danger of electric shock. The wire must be of the correct diameter to pass sufficient current to give the loading required, and of the proper length to absorb the voltage of the electricity supply.

The loading of immersion heaters is stated by the manufacturers in kilowatts

(kW) or sometimes in watts (one kilowatt equals 1,000 watts). The current in amperes (amps.) flowing through the heater may be obtained by dividing the loading in watts by the supply voltage. For example, a 3-kW immersion heater is to be used on a 240-volt supply; what load will the cables have to carry? 3 kW = 3,000 watts. The current will be 3,000 ÷ 240 = 12½ amps. Referring to the Table in the article on Cables (page 201), a suitable size may be chosen. If existing wiring is to be used, this information will render it possible to check the capacity of the wires, switches and fuses.

Loading. Recommended loadings for various capacities of storage vessels are given later in this article. These are for normal domestic use. For special requirements other loadings may be desired, and these may be calculated as follows:

It requires 1 B.Th.U. to raise the temperature of 1 lb. of water 1° F., and a gallon of water weighs 10 lb. The heat required in B.Th.U. to raise the temperature of G gal. of water T° F. is 10 GT. A kilowatt of electricity converted to heat is equivalent to 3,415 B.Th.U. The necessary loading of an immersion heater may, therefore, be found from the formula:

$$kW = \frac{10GT}{3{,}415} \text{ or } kW = \frac{GT}{341}$$

This gives the temperature rise per hour; if any other time period is given, the necessary conversion must be effected.

Example. A certain hot water supply installation includes a 100-gal. storage cylinder. After the peak demand for hot water there are 4 hours before a further large demand occurs. What should the loading of immersion heaters be for this installation?

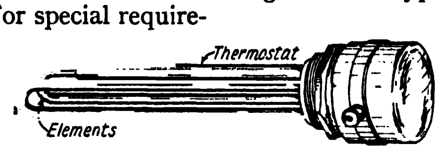
Assuming that at the conclusion of the peak load the average temperature of the water is 50° F. there are 4 hours available to heat it up to the normal temperature of, say, 150°F. This gives a temperature rise of $150 - \frac{50}{4} = 25°$ F. per hour. Adding 33⅓ per cent. to this or, say, 8° F. to allow for water drawn off during the heating up period and for radiation losses, the temperature rise becomes 33° F. per hour. Using the formula $kW = \frac{GT}{341}$ and substituting values, it becomes:

$$kW = 100 \times \frac{33}{341} = 9{\cdot}7.$$

A satisfactory installation would be three 3-kW immersion heaters.

Types of Heater. Two general types of immersion heater are manufactured: removable element and fixed element. The latter, if of the blade type, consists of nickel-chrome resistance ribbon wound on a mica former. The ribbon is further insulated with mica strips, the whole being inserted in a hollow metal former which is flattened under pressure. This brings about intimate contact between ribbon, mica and former, so that heat is readily transferred. This type is now mainly confined to small heaters used for boiling or heating water in saucepans or other small vessels.

The more usual type of fixed element heater consists of nickel-chrome wire spirals solidly embedded in refractory and insulating material. The whole mass is inserted in metallic tubes brazed to the fixing flange. Such a heater is shown in Fig. 1. A typical removable element heater is illustrated in Fig. 2. Here each element has an outer tube, usually of solid drawn copper which in some cases is tinned. The tube is brazed or welded into the fixing flange which secures the heater to the cylinder or tank. The heating elements themselves are spirals of nickel chrome alloy wire totally enclosed in steatite or porcelain bobbins which are a sliding fit in the copper tubes. The elements can thus be readily removed.



IMMERSION HEATERS. Fig. 1. Fixed element immersion heater: nickel-chrome wire spirals embedded in refractory and insulating material are inserted into metallic tubes.

This ready removal of the elements is an advantage, particularly as it may be done without emptying the storage vessel.

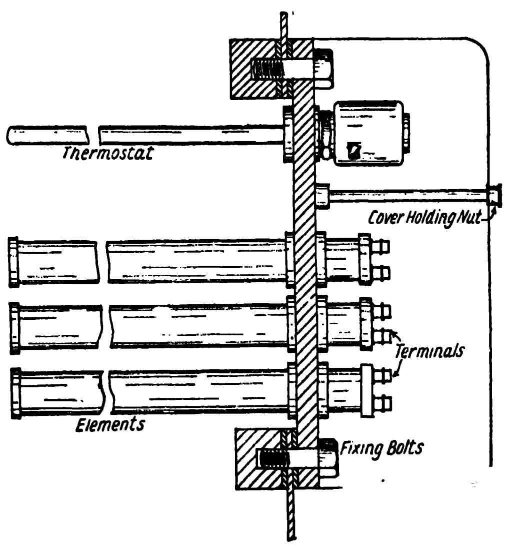


Fig. 2. Removable element immersion heater: spirals of nickel-chrome enclosed in steatite or porcelain bobbins which slide into drawn copper tubes.

But heaters of this description cannot be electrically loaded to such an amount as the fixed type heaters. This brings the advantage that the surface temperature is lower for the removable element type, with consequent slower incrustation in hard water districts. The corresponding disadvantage is that the heater is longer (*see* below), which may render it impossible to fix the removable element type in narrow tanks or in cylinders small in diameter. The fixed element type heaters are lighter in construction, which may be an advantage with flimsy tanks.

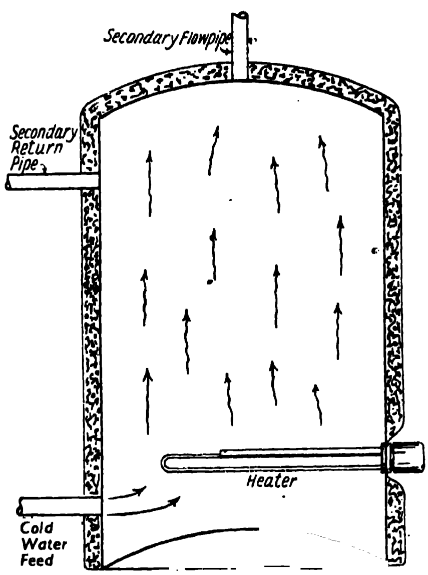
Fixing. The fixing flange may be secured to the cylinder with set-screws, as shown in Fig. 2; or may be screwed gas thread similar to Fig. 1. In the first case an inner flange is inserted through an oval hole in the cylinder. The face next the cylinder wall has a joint washer, and a similar washer is fitted to the outer flange carrying the heaters. The setscrews shown pull the flanges tightly against the joint washers, forming a watertight joint. In the case of the heater having a screwed head, round flanges are fixed inside and outside the cylinder wall. The outer flange has a female thread into which the heater head screws. (Further information will be found in the following section on the fitting of immersion heaters.)

Standard immersion heaters may be obtained having loadings of 1, $1\frac{1}{2}$, 2, 3 and 4 kW, meeting any normal requirements. Larger sizes and special loadings are made, but the standard ratings should be used where possible. The immersed lengths corresponding to the above loadings are, for removable element type: 11 in., 12 in., 16 in., 22 in. and 30 in.; and for the fixed element type: 11 in., 11 in., 11 in., 15 in. and 19 in. These are minimum lengths corresponding to the highest loading of the surface of the elements. This high loading means a high surface temperature, and in hard water districts would involve very heavy lime or magnesia deposits. When the apparatus is to be used with hard water, therefore, a heater should be chosen having a low loading.

The ends of the resistance wires are brought out to terminals which may be clearly seen in Fig. 2. The supply cables are connected to these terminals, the whole being enclosed by the cover shown.

Thermostatic Control. To ensure the lowest possible running costs it is essential that the heaters be controlled by thermostats. These are usually carried by the fixing flange, as indicated in Figs. 1 and 2. They are normally adjustable to break contact at any temperature between about 100° F. and 180° F., and are wired in series with the elements.

Two kinds of thermostats are in use. The mercury switch type is intended particularly for use on D.C. supplies, although it may be also used on A.C. supplies. In action an expanding rod tilts a glass tube in which two contacts are fused and which contains a small pool of mercury. When the tube is tilted sufficiently the mercury touches both contacts and so allows a flow of current.

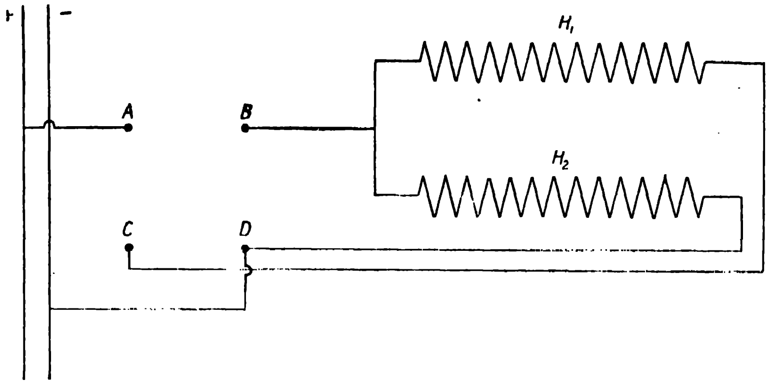


IMMERSION HEATERS. Fig. 3. Immersion heater in cylinder, setting up convection currents as shown by arrows.

The second type of thermostat (which must not be used on D.C. supplies) consists of an expanding rod which mechanically actuates a "snap" make-and-break. In either type the temperature at which the contact is broken and the current flow stopped may be adjusted by hand. It is usually set to occur at a temperature of about 170° F. With very hard water, if sufficient storage capacity is available, it is better to use a lower set temperature (say 140° F.) to avoid excessive lime deposit. As shown in Fig. 3, the heater must always be fitted with the thermostat on top.

Although thermostatic control is now inexpensive and is advantageous, hand control is still employed. In these cases a

4 pole 3-heat switch should be used, connected as Fig. 4, where H_1 and H_2 are two immersion heaters of equal loading. This switch in its first position connects



IMMERSION HEATERS. Fig. 4. Hand control for immersion heater, by 4-pole 3-heat switch : H_1 and H_2 immersion heaters ; A, B, C, D terminals on switch.

poles *a* and *c* so that the heaters are in series, giving quarter-heat. In the second position terminals *a* and *b* are connected. Only one heater is then in use, giving half-heat. For full heat pole *a* is connected to *b* and *c* to *d*, when the two elements are connected in parallel across the mains.

TABLE I

Loadings for Thermostatically controlled Installations

Capacity of Tank	Loading of Element	Recuperation Rate for 100° F. Rise	No. of Baths in Succession
gallons	kW	hours	
20	2·0	3·0	2
25	2·0	3·75	2
30	2·5	3·6	3
40	3·0	4·0	4

To obtain quicker deliveries of hot water, two immersion units can be used.

TABLE II

Loadings for Hand controlled Installations

Capacity of Storage Vessel	Loading
gallons	kW
15	2
25	3
40	4
60	6

Heater Rating. In determining the required rating of an immersion heater Table I may be used. This assumes thermostatic control. For use with hand control the suitable ratings are given in Table II. Both tables assume normal domestic use, with a few hours' heating-up period between peak loads. They are based on the assumption also that the capacity of the storage vessel is in proportion to the demand for water. This means that for each bath in the house there should be allowed about 20 gal. storage capacity. If the cylinder or tank is smaller than this, or if the demand for hot water is continuous, larger ratings are needed, and they should be calculated from the data given earlier in this article.

Immersion heaters warm the water in the storage vessel by convection currents, in the manner shown by Fig. 3. For this reason water below the heater will not become hot, and the heater must be fitted within 2 in. or 3 in. of the bottom of the cylinder if the whole contents are to be warmed. The clearance mentioned should be allowed, in order to collect sediment and scale. From Fig. 3 it will be evident that the hot water rising from the heater mixes with the cold water already in the cylinder. The temperature of the whole bulk of water therefore rises at the same time, and really hot water is not available until practically all the water is hot. This is one of the disadvantages of immersion heaters. To overcome this, where a tank or cylinder is large enough to require two heaters, it is recommended that one be fitted at the bottom and one half-way up. If the latter only be used, by operating the appropriate switches, only half the cylinder contents will become hot.

Reducing Heat Losses. Unless care is exercised electricity can be a very expensive method of heating water. This is particularly the case with immersion heaters, which are almost always applied to existing installations. In order to reduce running costs, every effort must be made to avoid radiation losses. The storage vessel must be thoroughly insulated. A " mattress " of the correct size, made of asbestos fibre or cork dust enclosed in a fabric casing, is probably the best method. The thickness should be $1\frac{1}{2}$ in. for good efficiency. Plastic

asbestos may be used, although it has the disadvantage of being messy. Also a good many asbestos compositions are so adulterated as to be very poor insulators.

A further source of radiation losses are circulating pipes. If these exist they should be cut out, or if they must remain they should be well insulated. It must be remembered that each foot of 1-in. pipe through which hot water is circulating gives off about 20 B.Th.U. per hour even when insulated. Ten feet will give off 4,800 B.Th.U. during 24 hours (equivalent to the waste of nearly $1\frac{1}{2}$ kW of electricity). This will amount to a really appreciable quantity during a year. Unfortunately the Metropolitan Water Board Regulations will not allow a tap to be more than 25 ft. from a circulation. If to comply with this regulation it is necessary to run a long circulation to an isolated tap, it is much better to give the tap its own independent water heater and to cut out the circulation.

An immersion heater is essentially a method of converting an existing installation. For a new installation, storage heaters are better (*see* Thermal Storage Heaters). If small quantities of hot water are required quickly, an electric circulator is better, although it does not heat the whole bulk of water any quicker than an immersion heater. If the cylinder is of the indirect type an external circulator is the only possible fitting. If there are a number of scattered hot water points, a conversion is better avoided, and separate storage heaters should be used for each tap or group of taps.

The heater should be fixed so that it is accessible for de-scaling. The tank or cylinder must have a manhole for de-scaling. The general arrangement of piping must be suitable for use with an immersion heater. This is dealt with in the following Section, on the fixing of immersion heaters.

Running Costs. The running costs of electric water heating may be found as follows. Taking about 90 per cent. efficiency to allow for radiation losses, each kilowatt is equal to about 3,000 B.Th.U. or 3 gal. of water raised 100° F. in temperature. A hot bath requires 15 gal. of such water, or 5 kW. The average consumption of hot water per person per day is about 25 gal., or about 8 kW. Knowing the price of electricity, the running costs may be obtained from these figures.

B. INSTALLATION AND FIXING OF IMMERSION HEATERS

In the first Section of this article information is given on types of heater, and on rating and loading. There also is a description of the method of determining the rating necessary for any given cylinder and tank. In the articles of the Hot Water group will be found general information on principles and methods, and the reader should refer there for supplementary notes not included in the present contribution, where we are concerned only with the installation of the particular type of apparatus in question.

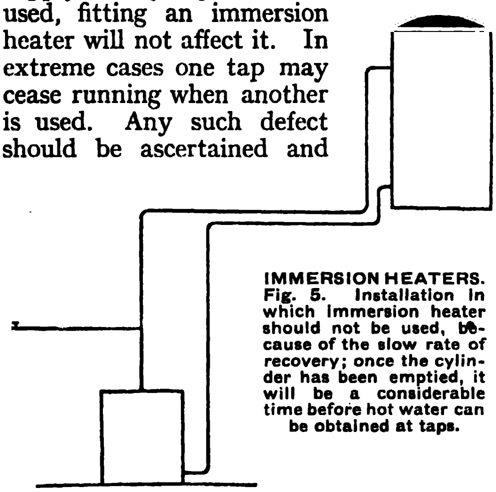
Conversion of Installation. Since immersion heaters are almost always used for the conversion of an existing installation for use with electricity, the first step is to determine whether satisfactory results will ensue after the conversion. Of prime importance is the capacity of the storage vessel. When a boiler is used it is possible to "force" it in order to meet a large demand for hot water: in this way it is possible to overcome any lack of storage capacity, since the boiler will probably be capable of heating the water content in less than an hour. On the other hand, the rating of immersion heaters is usually so chosen that they take two to three hours to heat up the water in the cylinder or tank. Larger heaters will considerably increase the first cost of the installation, and may require cables larger than usually found.

For average household use, not less than 25 gal. storage capacity should be provided for each bath installed. This assumes that not more than two baths will be taken in succession. For each additional bath likely to be taken, an additional 10 gal. to 12 gal. should be provided in the storage vessel. For larger buildings, such as flats, offices, etc., the particular needs will determine whether any given storage capacity will be sufficient.

The position of cylinder or tank must be suitable: it must be accessible for fitting the heater, but of equal importance is the space around it. The tank or cylinder must have about 2 in. of insulation on all sides and on the top. There must be room for this and also space to apply it.

Linen Cupboard. Where the storage vessel is fixed in a linen cupboard and is the sole means of warming it, two methods may be adopted. Part of the insulation may be omitted so that some warmth is available. This has the disadvantage that the heat cannot be controlled. A better method is to provide tubular heaters which can be switched off when not required.

Piping. The arrangement of the piping should be studied. If an unsatisfactory supply at any tap occurs when a boiler is used, fitting an immersion heater will not affect it. In extreme cases one tap may cease running when another is used. Any such defect should be ascertained and rectified. An arrangement like Fig. 5, where taps are supplied from the boiler flow pipe which connects to a low point in the cylinder, is particularly bad. Owing to the slow rate of recovery, it will be found that once the cylinder is emptied of hot water it will probably be at least two hours before hot water can be drawn at taps so connected.



IMMERSION HEATERS. Fig. 5. Installation in which immersion heater should not be used, because of the slow rate of recovery; once the cylinder has been emptied, it will be a considerable time before hot water can be obtained at taps.

In addition to the general arrangement of the piping, the runs should be investigated. Circulations must be avoided. If local Water Board regulations specify maximum allowable lengths of dead legs (pipes in which no circulation takes place), local heaters should be used for taps distant from the tank. The circulations which exist should be cut and plugged. If this is impossible the circulating pipes should be wrapped with asbestos felt to reduce heat losses to the minimum. If it is evident that the circulation will be a brisk one, it is wise to insert a valve which can be adjusted to reduce the rate of circulation. If a heated towel rail is fed from the hot water pipes, it is better to replace it with an electrically heated rail. This is more easily controlled and is more likely to be switched off when not wanted.

Preliminary Inspection. Having checked that the heater will not be too long for the tank, nor foul any pipes inside it, the installation may be begun. The system should, of course, be emptied. If a manhole is fitted, the cover should be removed and the interior of the tank cleared of scale. When this has been done an examination should be made for pitting. If the metal is in bad condition, it is better to explain to the owner that a new tank would be a good investment. When tank failure occurs a short time after the fixing of the heater, the latter is likely to be assumed as the cause of the failure.

Fitting the Heating Element. The most suitable position for the heater is two to three inches clear of the bottom of the tank and as nearly as possible on the centre line. This will mean, with the usual heater, that its centre point will be about 5 in. above the bottom of the tank. There must be sufficient clearance to insert and withdraw the element, so that the only possible position will be the front face of the tank. Accordingly, a mark should be made with a centre punch in the position which the centre of the heater will occupy.

Most immersion heaters screw into round or oval flanges, a section through the fixing being given in Fig. 6. One of the flanges should be used as a template, being placed on the side of the tank with its centre coincident with the punch mark already made. The bolt holes and clear-

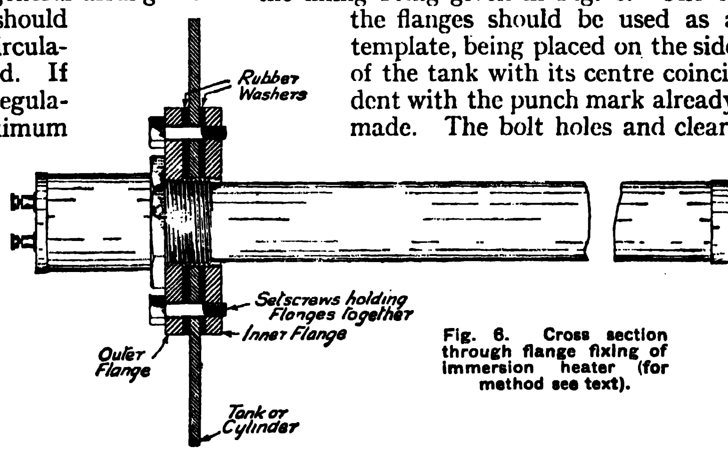


Fig. 6. Cross section through flange fixing of immersion heater (for method see text).

ance hole for the heater should be outlined. The former may be drilled with an ordinary breast drill. For the clearance hole a tank cutter (*see* Drill and Drilling Machine) should be used.

If this is not available a cold chisel is the quickest method with thin metal. A block of wood held inside the tank will take the blows on the chisel. If the tank is of thick metal drill a series of holes around the clearance hole circle and join them up with a hacksaw or a cold chisel.

The inside and outside faces of the metal where it has been cut should be thoroughly cleaned and all burrs removed. Any scraps of metal which have dropped into the tank should be removed, to prevent subsequent chemical and electrolytic action and consequent wasting and pitting. The flanges may then be fitted to the tank. A rubber washer should be fitted between flange and tank for both inside and outside flanges. If such washers are not provided they may be cut, using the flange as a template. Setscrews and nuts with washers under the heads hold the flanges together. The setscrews should be long enough to project about two threads through the nuts and should have a little hemp wound under the heads.

Where the heater incorporates its own thermostat no further provision is necessary for this. If a separate thermostat is to be used, flanges of appropriate size must be fitted to the tank to take it. The best position for it is about 4 in. to 6 in. above the heater and slightly to one side of the latter. If more than one immersion heater is being applied to a tank, the first should be fitted near the bottom, as described above, while the second one should be half to two-thirds up the tank. When the heater is being used in conjunction with a cylinder, flanges bent to the proper radius must be employed.

Testing. After the work on the flanges is completed the manhole cover may be replaced, the heater screwed home and the wiring carried out. The installation should then have a heat test for some little time. Defects such as leaky bolts may be detected and remedied. After making sure that everything is sound, the insulation can be applied. This may take several forms, one of the most efficient being an asbestos mattress not less than 1½ in. thick. These may be obtained made to fit the tank or cylinder. Asbestos is an efficient insulator and vermin proof; any other material used should have the same properties. Where a jacket is not used a common method of insulation is to make a wood framework round the tank with panels of closely woven canvas. The space between tank and canvas (which should be not less than 3 in.) is then filled with cork dust.

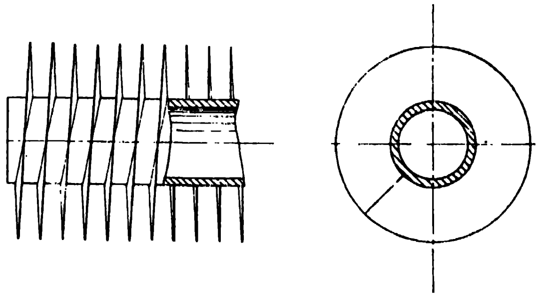
Electrical Work. The electric supply to an immersion heater should not be taken from a plug point but should come direct from the distribution board. The meter and main switchgear must be large enough to carry the additional load which, in the case of a 3-kW heater, for example, will amount to at least 12½ amps. For the proper size of cable *see* Cables. A switch should be inserted in the supply to the heater and near the heater. If this switch is of the single-pole type, it should be in the live lead. It should preferably be of the insulated type, and both this and all other parts of the electrical installation should be out of reach of anyone in the bath. This is based on the assumption that the linen cupboard is in the bathroom, as is often the case.

The metal casing of heater and thermostat should be well bonded to earth. It is a wise precaution to earth all pipes in a bathroom also. Any wiring in a linen cupboard should preferably be carried out in asbestos sheathed fireproof cable. The remaining cable may be of any suitable type. The thermostat should be wired in series with the immersion heater. If these two are separate fittings, it may be found that the heater has one red and two black terminals for used with a three-heat switch control. In this case, for complete thermostatic control, the two black terminals should be coupled together and treated as one. The electric cables should be controlled near the main distribution board by a double-pole switch and fuses.

INDIRECT HEATER. Used for warming a room indirectly, the heater being outside the room. It consists of a heating element enclosed in a casing and communicating with the room to be warmed. Air passes over the heater through the casing, becomes hot and enters the room. The air flow may be due to natural convection currents created by the warmed air being lighter than the surrounding air (gravity indirect heater). In other cases the air may be forced over the heater by a fan.

The source of heat may be hot water, steam or electricity. For hot water and steam, either ordinary radiators or special extended surface heaters may be used. The latter are of the gilled pipe type similar to Fig. 1, or the fin type shown in Fig. 2. In both cases the heater includes a number of projections through which the air passes, coming into intimate contact with them and absorbing heat.

Hot Water or Steam Type. A typical installation of hot water or steam indirect heater is given in Fig. 3. Assuming a ground floor room, the heater is suspended from the basement ceiling by means of rods and mild steel angles. It is enclosed in a galvanized sheet steel casing having a space at the top and bottom. Into the bottom space enter the re-circulation duct and



INDIRECT HEATER. Fig. 1. Gilled tube indirect heater, shown (left) in part elevation and part section and (right) in cross section ; the heating unit is warmed by hot water or steam and placed outside the room to be heated.

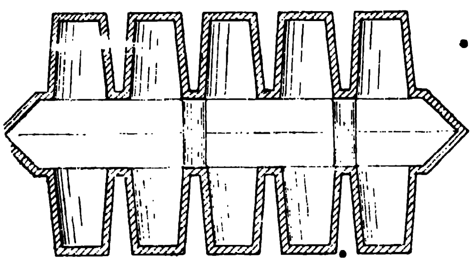


Fig. 2. Section of fin type indirect heater, warmed by hot water or steam.

the fresh air duct. These ducts are controlled by dampers, which are so interconnected that as one of them opens the other closes. By operating these dampers all fresh air, all room air, or any mixture of both may be allowed to flow to the heater.

If it is intended that the heater shall ventilate the room as well as warm it, the re-circulation duct and dampers may be omitted. If, on the other hand, the heater is used only to warm the room, the fresh air duct and the dampers will not be required. After the air has been warmed by the heater it rises, owing to its decreased density, through the delivery duct into the room.

In the design of such an installation it may be taken for hot water that if fresh air is used the air will enter the room at about 85° F. ; and if re-circulated air is used the temperature will be about 100° F. Assuming a room temperature of 60° F., the quantity of air required to flow into the room may be found by multiplying the heat loss by 55, dividing by 25 for fresh air and by 40 for re-circulated air. This will be cu. ft. per hour. Division by 60 gives cu. ft. per minute (c.f.m.).

In the ducts an air speed of 200 f.p.m. may be allowed for the floor directly above the heater, and 300 f.p.m. for rooms on the floor above that. If the air quantities in c.f.m. found above are divided by these speeds, the required area of the ducts in sq. ft. is obtained. The ducts should be as direct as possible with easy bends to avoid friction. The heater casing should fit the heater closely at the sides, and the spaces above and below the heater should be not less than 6 in. Adequate flow and return pipes should be used to the heater, and care should be taken that it is properly vented.

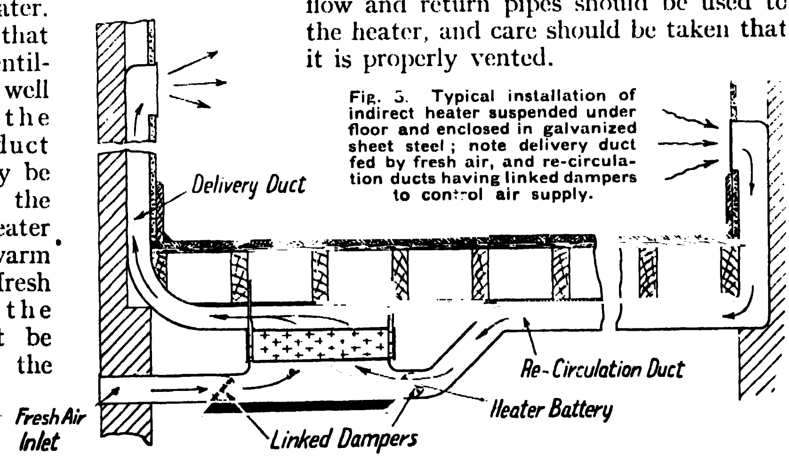


Fig. 3. Typical installation of indirect heater suspended under floor and enclosed in galvanized sheet steel ; note delivery duct fed by fresh air, and re-circulation ducts having linked dampers to control air supply.

Heating Surface Required. The heating surface necessary in the heater may be found by dividing the room heat loss by 150.

Example. A room having a heat loss of 8,000 B.Th.U. per hour is to be warmed with an indirect heater on the ceiling of the floor below. No fresh air to be used.

Air quantity will be $\frac{8{,}000 \times 55}{40}$ = 11,000 cu. ft. per hour = 183 c.f.m. Air speed will be 200 f.p.m. and duct area 183 ÷ 200 = 0·92 sq. ft., or say 132 sq. in. The duct could be 12 in. × 11 in. The heater would need a heating surface of 8,000 ÷ 150 sq. ft. = 53 sq. ft.

Electric Heaters. When electricity is the heating medium the arrangement is similar to Fig. 3. The heater then consists of resistance wire mats. For the use of indirect heaters with fans the articles on Plenum Heating *and* Ventilation should be consulted. *See also* Fan.

INSPECTION CHAMBERS ON DRAINAGE SYSTEMS

By H. C. H. Shenton, F.R.San.I., Hon. F.I.S.E.

Setting out the essential requirements for access and observation. Though details of the brickwork to chambers lie outside the scope of this work, notes are given of the most important features. In the following section Cast-Iron Inspection Chambers are dealt with. *See also* Drains and Drainage: Sections (1), (3) and (4); *also* Intercepting Chamber; *and* Manhole.

Inspection chambers, as the name implies, are provided in order that the working of any drain or system of drains may be kept under observation; it is also necessary that the chambers should be so formed that they will provide access to the drains for cleaning and for testing. The efficiency of any system of drains is dependent largely upon the provision and proper arrangement of these chambers, and economy of construction is also affected materially.

In designing an inspection chamber it is necessary to consider the requirements of each separate case, which will differ with the depths and positions of the drains at each point where it is necessary to provide means of access. The first requirement in all cases is that it shall be possible to see all drains running into or from the chamber, and that it shall be possible to pass cleaning rods through each pipe and also to insert plugs for stopping the ends of the drains when testing, the plugs being those which are commonly used for the purpose (*see* Drains: (3) Examination and Testing). The chamber must also be so arranged that there will be no difficulty in cleaning the interior.

Appropriate Size. It is very important to understand that as long as an inspection chamber fulfills these simple requirements there is no object in increasing its size. On the other hand, the chamber will not serve its purpose effectively unless it is of such a size and shape that it will provide proper access and working space. Thus in the case of an iron drain above ground level a simple inspection opening in the pipe itself with a bolted cover is sufficient.

If this drain should be, say, 12 in. below ground level, it is clear that the same arrangement would suffice, but that it would be convenient to enclose it in a brick or concrete pit with an additional cover at ground level; and that in the case of a stoneware drain open channels might be provided in such a pit. The pit could be of small dimensions because the pipes and channels would be reached easily by hand.

With a deeper pit on a straight drain, greater length might be necessary in order to make possible the insertion of drain rods; and if one or more side branches occurred, greater width might be required for the same reason. But as long as the ends of all pipes could be easily reached by hand, there would be no advantage in making the chambers of greater length or width than would be necessary for rodding.

Manhole and Cover. The size and arrangement of the cover must, of course, be carefully considered with the same ideas in mind. Up to depths of about 2 ft. 6 in. the chambers will therefore generally be of small size, but between this depth and a depth of about 5 ft. there are a variety of possibilities which may make it desirable to have larger covers, so that a workman can enter the chamber and work with his head above ground, or unobstructed by the roof of the chamber, with vision of the interior as required.

The chamber must in such cases be large enough to enable a man to sit or kneel when cleaning, working rods, or inserting plugs; and be wide enough to give elbow room. It is a common error to make such chambers so that the work can be performed only with the greatest difficulty, if at all.

Fixed dimensions are not applicable; the size of the chamber and the arrangement of the cover must be dependent upon the positions of the drains and branches. With good design there will be an avoidance of unnecessary size and cost of construction, while there will be great saving in the cost of maintenance because all necessary operations can be carried out easily and quickly.

Deep Chambers. With chambers exceeding 5 ft. in depth a working space is provided of the necessary area with a headroom of about 4 ft. above the channel benching. Access to the chamber is obtained by means of a shaft which should be at least 21 in. square even for shallow depths; while for greater depths it should be at least 2 ft. square. This shaft is carried up to the ground surface and should be provided with a cover having a clear opening not less than 21 in. square.

Brickwork to Inspection Chambers. Inspection chambers are provided at changes of direction on the drainage system, thus avoiding the need for sharp bends in the pipes. They are built in the same manner as intercepting chambers (*which see*), but, of course, no intercepting trap is provided. The chamber should be constructed of good hard and impervious bricks, all the internal surfaces being cement rendered. The open channels at the bottom are made of half-section pipes and must be well benched up on each side so as to keep the chamber clean and prevent sewage adhering. An air-tight inspection cover is provided at the top. *See* Manhole.

Access Chamber. In the case of iron drains below ground, the inspection chamber is of cast-iron and is enclosed in an access chamber built in brickwork and furnished with a cover in the usual way. The inspection chamber is sealed by an iron cover bolted to the flange with corrosion-resisting bolts and nuts, a greased felt washer being interposed to make an air-tight joint. *See* Manhole.

INSPECTION CHAMBER IN CAST-IRON

By D. Longden, M.R.San.I.

Cast-iron inspection chambers (Figs. 1 to 6, p. 608) take the place of open stoneware channel bottoms in manholes and, in addition, are used on suspended drains within buildings where the ordinary manholes would be impracticable.

Where drains cross fields it is not necessary to form manholes if cast-iron inspection chambers are used. Many consultants ask for a mark plate only, the ground being dug up to give access to the inspection chamber in case of emergency. In the ordinary way, however, brick manholes are built around inspection chambers, and it is essential that these be watertight so as to prevent water percolating through the walls and collecting in the manhole.

The standard cast-iron inspection chamber consists of a pipe with the ordinary spigot and socket but with a long opening in the centre, formed as it were by opening out the pipe and turning over at the top to form a flange. The flange has bolt holes and upon it is seated a greased felt washer made of blanket felt dipped in tallow. The cover plate fits exactly over the flange, to which it is bolted by means of ⅝-in. galvanized iron bolts and nuts, ½-in. gunmetal bolts and nuts or by ⅝-in. manganese bronze bolts and gunmetal nuts.

Galvanized-iron bolts should be avoided; the threads cannot be galvanized, and they corrode very rapidly in the atmosphere of the manhole. Manganese bronze bolts and gunmetal nuts are exceedingly strong and do not corrode. When jointed, the inspection chamber is thoroughly gas-tight and is capable of withstanding considerably more than the test pressure of 5 ft. head.

Stock Sizes. Inspection chambers are made without and with branches; those without branches and those with one branch having a clear opening of the diameter of the pipe by 12 in. long. A chamber with one branch, or one branch on each side, is of the same size and thereafter branches are at 10-in. centres.

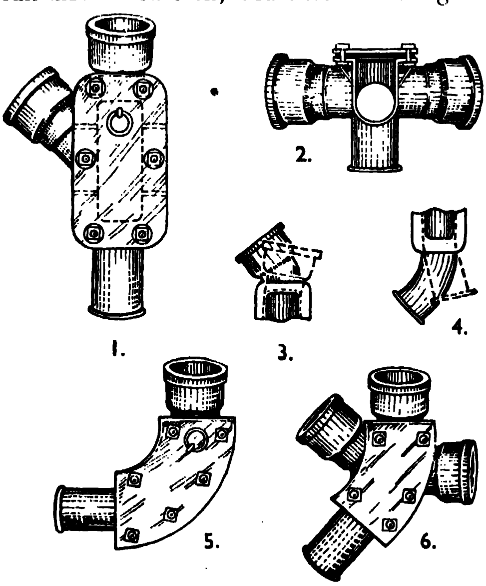
The flange is 2 in. wide all round, and the spigot is 8 in. long from the outside of the flange.

Inspection chambers are stocked by merchants in forty-three varieties, each of 4 in. × 4 in. and 6 in. × 4 in. sizes. There is a considerable selection of 5 in. × 4 in., 9 in. × 4 in., 9 in. × 6 in., and 9 in. × 9 in. sizes; but in the case of 9-in. chambers the stocks usually available have one branch only, or one branch on each side.

The standard angle of branches is 135 deg., although, in single-branch chambers of 4 in. diameter, 90 deg. and 112½ deg. are obtainable. The angle of 135 deg. is most suitable, because the branch is given a good run into the main, and standard bends affecting direction and inclination can be applied to meet the point of origin of the branches.

Inspection chambers may be specially cast with bottom outlets (Fig. 2), of which more is said in the article on Intercepting Chamber (*which see*).

Other special features which can be applied to inspection chambers are bent inlets (Fig. 3) and bent spigot outlets (Fig. 4); both of these save the use of a bend on the consequent joint, but hamper rodding. Reducing socket inlets can also be cast on, and these should give



INSPECTION CHAMBERS. **Figs. 1–6. Cast-iron inspection chambers: (1) horizontal outlet and bolted cover, stocked 4 in. × 4 in., 6 in. × 6 in., and at 135 deg.; (2) vertical or bottom outlet, stock angle 135 deg.; (3) bent inlet socket; (4) bent spigot outlet; (5) curved chamber with bolted cover, stocked 4 in., 5 in., and 6 in. diameters, and at 90 deg., 95 deg., 100 deg., 112½ deg.; (6) curved chambers with bolted cover, stocked 4 in. × 4 in., 5 in. × 4 in., 5 in. × 5 in., 6 in. × 4 in., 6 in. × 6 in., and at 135 deg.** (*Burn Bros., Ltd.*)

a level invert, a cascade effect being objected to by some authorities. In addition to the straight chambers mentioned, others curved to 90 deg., 95 deg., 100 deg., 112½ deg., and 135 deg., are obtainable (Fig. 5); and one branch may be cast on each side, as Fig. 6. Curved inspection chambers are stocked 4 in., 5 in. and 6 in. diameter.

INSTITUTE OF PLUMBERS. The Institute of Plumbers, founded in 1907, has for its principal objects the promotion and protection of the plumbing craft. To that end it has established contact with such Government departments as the Ministry of Health and the Board of Education, and by means of its technical publications is recognized by local authorities as the technical body with authority to represent the master plumber.

Recognizing that efficiency must depend on the sound training and education of the whole personnel of the craft, it co-operates closely with the City and Guilds of London Institute (*which see*), and has strongly supported schemes of indentured apprenticeship.

Its membership consists of four classes:

Fellows (Fellow I.O.P.)—a distinction awarded for very distinguished service to the Institute.

Honorary Members—awarded for special service to the craft.

Elected Members (M.I.P.)—Master Plumbers, who satisfy the Council as to their status and efficiency.

Associated Members (A.M.I.P.)—Persons, not being Master Plumbers, who satisfy the Council as to their attainments, special knowledge of and connexion with the craft.

Throughout its existence the Institute has increasingly been concerned with the varying interpretations of the standards laid down in sanitary and water by-laws.

Further, although the Ministry of Health issues model by-laws, these cannot be expected to set out the detailed manner in which such work should be carried out.

In 1930 the Institute set up a special Committee to draw up Minimum Specifications (*which see*) for plumbing work.

This Committee's work includes the following Specifications:

No. I. For the Installation of Soil, Waste and Ventilating Pipes (including the One-Pipe System of Plumbing).

No. III. Drainage Work in Connexion with Buildings.

No. IV. The Installation of Hot and Cold Water Services (incl. No. II).

purchasable from the Institute.

The Institute also closely collaborates with the British Standard Institution.

It administers the J. P. Cox Memorial Prize Fund and presents medals and prizes on the results of the City and Guilds Examinations. It also awards a Technical and Administrative Diploma on an examination based on a knowledge of the problems of an employer's business in all its aspects. Particulars are available from the offices of the Institute at 81, Gower Street, London, W.C.1 (Secretary, H. Blackman, B.Sc., F.R.Econ.Soc.).

INSTITUTE OF WELDING. Founded in 1923 to promote the advancement of the science and practice of welding. It has a comprehensive library of welding literature and provides a technical information service and an Appointments Register. There are 20 branches and sections in the United Kingdom and one in India. Meetings are held regularly in London and the chief industrial centres.

The Institute publishes Transactions and a " Handbook for Welded Structural Steelwork." It is a Founder Member of the International Institute of Welding of which its Secretary, Mr. G. Parsloe, 2, Buckingham Palace Gardens, Buckingham Palace Road, London, S.W.1, was, in 1948, the Secretary General.

Membership. The Institute includes: Members; Associate Members; Industrial Corporate Members (companies and firms); Companions ; Graduates ; Associates and Students. Admission for Associate Members, Graduates and Students is by examination held in January and July each year. Qualifications and terms of appointment are obtainable from the Secretary.

INSTITUTION OF ELECTRICAL ENGINEERS. Founded in 1871 as the Society of Telegraph Engineers which became in 1888 the Institution of Electrical Engineers and was granted a Royal Charter in 1921. Its premises, acquired in 1909, are on the Embankment at Savoy Place, W.C.2. Its objects as set out in the Charter are :

To promote the general advancement of Electrical Science and Engineering and their applications, and to facilitate the exchange of information and ideas on these subjects by means of meetings, exhibitions, publications, the establishment of libraries, the giving of financial assistance for the promotion of invention and research.

The Institution holds meetings at which papers are read and discussed but equally important work is done by the Council and its Committees, including the Wiring Regulations Committee, and the Ship Electrical Equipment Committee, both of which include persons from outside the Institution. Important sections are those concerned with Measurements; and Radio Supply and Utilization. Students and Graduates meetings for reading and discussion of papers are held in London and 15 other centres.

The Institution works for the advancement of electrical engineering science and the improvement of practice. Although the famous wiring regulations of the Institution (*see* I.E.E., Regulations) do not possess legal force their observance is obligatory in the circumstances explained in page 597. The Institution is responsible for Regulations for the safe and efficient wiring of premises for lighting, heating and power, Regulations for the electrical equipment of ships and aircraft, and has advised the Ministry of Fuel and formerly the Electricity Commission, on draft Regulations for overhead electric lines. As one of the constituent bodies of the British Standards Institution and of the International Electrotechnical Commission, the Council support the issue of Standard Specifications.

Since its earliest days the Institution has been interested in research and is now closely linked with the British Electrical and Allied Industries Research Association. The Institution is vitally interested in the education and training of engineers and collaborates with the Ministry of Education.

The Institution has a Library of about 20,000 volumes with a lending section, and publishes Proceedings, a monthly journal, and " Science Abstracts."

Membership of the Institution includes : Members ; Associate Members ; Companions ; Associates ; Graduates and Students, the total in 1948 of all classes being 33,588. Corporate Members, i.e. Members and Associate Members have exclusive use of the letters M.I.E.E., and A.M.I.E.E., respectively. Members of these two classes have also the right to the title of Chartered Electrical Engineer.

INSTITUTION OF GAS ENGINEERS. Founded in 1863, incorporated in 1902, and granted a Royal Charter in 1929, with premises at 1, Grosvenor Place, London, S.W.1. Its chief aims are to bring about both practical and scientific improvements in the gas industry, and to increase the application of gas to lighting,

heating, production of power, for domestic and industrial uses.

The Institution has set up a number of committees dealing with research and technical investigation. These committees draw up or assist in drawing up Specifications, Codes of Practice and the like.

Tables from the Institution's Report on "Gas Installations" (published 1944) are reproduced in our pages, by permission.

The Institution has schemes of education, operated at many colleges throughout Great Britain, catering for the needs of gas engineers, gas salesmen, and gas fitters.

Membership. The Institution includes six classes of members. Members are required to hold the Diploma of the Institution or a specified degree ; Associate Members and Associates the Higher Grade Certificate or other qualifications approved by the Council. Examinations are held every year for the Diploma, Higher Grade Certificate or the Ordinary Grade Certificate required for Students.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS. Founded in 1897, and now established at 75, Eaton Place, London, S.W.1, its object is to promote the science and practice of Heating, Ventilating, Air Conditioning, Drying, Domestic Hot Water Supplies and all branches of engineering kindred thereto. There are seven provincial branches established in the United Kingdom, with a London Associate Members' and Graduates' Section.

Membership. The Institution consists of Honorary Members, Members, Associate Members, Associates, Graduates and Students. The Council elects to honorary membership only those persons of eminent scientific attainments or such distinguished persons who have rendered special services to the Institution. Members are persons who have qualified for Associate Membership and have acquired an established reputation as heating or ventilating engineers. Associate Members are persons who have passed the Institution examination or an exempting examination and have received an approved training and have held a position of technical responsibility in heating and ventilating or a branch of engineering closely allied technically thereto.

Associates are persons engaged in responsible positions in the science or practice of heating or ventilating engineering, but not qualified for corporate membership. Graduates are persons not under the age of 21 years, who are in the process of qualifying for Associate Membership and who have passed the graduateship examination. Students are not under 16 years of age and have satisfied the Council that they are receiving approved training in practice and theory.

Examinations. The associate membership examination consists of two parts. The first covers technical drawing, calculations and mensuration, and mechanics and physics applied to heating and ventilation; the second covers heating and hot water supply, central station layout, ventilation and air conditioning, and calculations, layout and performance tests. The graduateship examination covers drawing, calculations and mensuration, mechanics and physics, elementary principles of heating and ventilation.

Library and Publications. Members may use the library for reference and for the borrowing of books.

The monthly Journal and the Guide to Current Practice are issued free to members. Extracts from the latter in booklet form may be purchased.

INSTITUTION OF SANITARY ENGINEERS. Founded in 1895 and incorporated in 1916, with premises at 118, Victoria Street, London, S.W.1. The main objects are to promote the interests of the profession, to raise the status of its members, and to encourage a high standard of proficiency. The Institution undertakes to consider all problems affecting the profession ; to take any steps necessary to support, amend or oppose any Act of Parliament or regulation affecting it ; to encourage honourable practice and to suppress malpractice.

A library and an information bureau are open to members. Papers and books are published and printed, and a Journal is issued quarterly. Sessional meetings are held in London during the winter for the reading of papers, and during the summer visits are arranged.

Examinations. The Institution grants medals and certificates of competency in professional knowledge. Examinations are conducted twice a year, viz. in May and November, for the Associate Membership and Membership grades. They are held in London and are also held at centres in the provinces and overseas as may be

necessary. These examinations cover general education; sanitary science; water supply; drainage and sewerage; sewage and refuse disposal; building constructions; specifications, quantities and estimates; lighting, heating and ventilation; setting out and supervising works; surveying; and sanitary law. They are accepted by local authorities and others as evidence of proficiency.

Grades of Membership. There are six grades of membership. Of these, Fellows, Members and Associate Members are corporate members; whilst Honorary Fellows, Associates and Students do not share in the full privileges of corporate membership. An Honorary Fellow is distinguished for his service to the cause of public health or the progress of sanitary science. The number is strictly limited. Fellows are promoted by the Council from the grade of Members for outstanding merit in the profession. Members and Associate Members must have passed the Institution's qualifying examination or such other examination as may be accepted by the Council. Applicants for the Studentship grade shall be studying sanitary engineering and shall have passed the Common Preliminary Examination of the Engineering Joint Examination Board or have a qualification exempting therefrom.

INSULATING MATERIAL. It is difficult to define an insulating material (also called an *insulator* or *dielectric*), because there is no hard-and-fast dividing line between materials of this class and electrical conductors. In the early days of electricity it was thought that there was such a dividing line and that insulating materials did not conduct electricity, but it is now known that all materials are conducting when a voltage is applied, though the current flow may be infinitesimal.

Insulating material is used to separate live conductors from one another and from earth, thus preventing short circuits; and to prevent danger to life by accidental contact with live metal.

When forming the dielectric of a condenser it has an additional function, for on being put into a state of strain by an applied voltage it stores an electric charge for a greater or less time.

Insulating materials are both numerous and diverse and include most, but not all (*e.g.* electrolytes) of the non-metallic substances. They may be gaseous, liquid or solid. No single insulating material has such a combination of properties that it is of universal application, and in deciding on a material for a particular purpose a compromise often has to be effected.

High electrical strength is not the sole criterion of a good insulator; mechanical properties, workability, resistance to heat and moisture, and method of application are usually of equal importance. Some materials (*e.g.* paper and cotton) are hygroscopic (*i.e.* absorb moisture from the air) in their natural state, and it can be taken as a general rule that the presence of moisture lowers the electrical strength of the material. To overcome this defect such materials may be dried and impregnated with an insulating material—varnish, oil, or bituminous material. The simplest method is to air-dry in an oven and then dip in the desired medium. In the case of varnish impregnation this may be followed by baking, according to the nature of the varnish and the directions of the manufacturer. Better results are obtained if the articles are dried under vacuum and impregnated under pressure.

Many insulating materials will not stand a high temperature for any length of time, and if so exposed become charred or crumbly, and cease to serve the purpose for which they were employed. Others "track" when subjected to an arc or spark. This track conducts at a lower voltage than the original substance and may sooner or later lead to complete breakdown of the material.

It is impossible in a short compass to describe all the various insulating materials and their properties, but a few typical ones are described below.

Gaseous. The most important gas used for insulating purposes is *air*. This is universally available and, except when in a state of ionization, has infinite resistivity. Nitrogen is used for gas-filled cables and capacitors and in high-wattage electric lamps. Argon is also used in electric lamps. Hydrogen is used as an insulating and cooling medium for large alternators.

Liquid. The only liquids used to any extent as insulators are refined mineral oils. These are used mainly for transformers and switchgear.

Semi-fluid and Fusible. These are used for filling cavities both large and small (for example in certain types of

transformers and switchgear, and in junction and sealing boxes) for impregnating porous and hygroscopic materials ; for bonding laminated materials ; and for moulded compositions.

Some of the fusible materials are *thermo-plastic* (*i.e.* they soften with heat and harden on cooling—the process being repeatable) ; others are *thermo-setting* (*i.e.* after undergoing a heating cycle they become permanently hard).

Bitumens are very water resistant and have good electrical properties. Bituminous compounds are available with a great variety of physical properties. (One manufacturer lists over a thousand.) High melting point compounds tend to be brittle at ordinary temperatures.

All have a high coefficient of expansion and care must be taken in filling and cooling to prevent voids and cracks.

Waxes. Natural and synthetic waxes are frequently employed for impregnating condensers and radio coils.

Thermo-Plastic Resins. These soften when heated within a certain range of temperature, and may be cast, formed, moulded or extruded.

As examples of this class may be mentioned Polythene (Alkathene), a general name for a series of wax-like substances readily moulded by injection or extruded as tubes or coverings on wires and cables. Chiefly used for high voltage and high frequency work, such as radar.

Polyvinyl acetate (derived from acetylene or cracked petroleum gases) used as an adhesive and when treated with formalin produces a material for covering wire and bonding veneers.

Polyvinyl chloride (P.V.C.) when suitably compounded produces rubberlike substances which are suitable for covering wires and cables. Being extensively used.

Nylon. The electrical properties of this class of material are not high, but are better than those of natural fibres. When suitably modified is used for producing synthetic enamelled wire.

Thermo-Setting Resins. The earliest synthetic resins of this class are of the type generally but inaccurately referred to as Bakelite (although this is a registered trade name) and sometimes as phenol formaldehyde resins, after the raw material of their manufacture. They are available in a wide range of characteristics and may be syrupy liquids or, more usually, solids of low softening point. Depending on the process of manufacture the curing time (*i.e.* the time required to make permanently hard and insoluble) varies from a few minutes to several hours. In the soluble form they may be used for coating paper or fabric or bonding laminated material (which may subsequently be cured, or used for making varnish).

Their widest application is, however, in the manufacture of moulded materials and articles when used to bond suitable fillers such as finely ground wood-flour, or powdered mineral (such as mica) or asbestos.

Bakelite mouldings have found a great variety of uses.

A newer material which has better resistance to heat and tracking than the bakelite type, combined with good resistance to moisture, is being marketed under the trade name of " Melmac."

Silicones are an entirely new class of material which has recently been produced, able to withstand high temperatures almost indefinitely.

Solid Materials. Mica and slate and marble are among the oldest of natural inorganic solids to be used as insulating materials—the two last being used for switchboards and terminal boards. Mica is now chiefly used in the form of bonded sheets or flakes and may be also obtained stamped as washers or pressed and moulded as bushes or formers. Electrical porcelain finds a variety of uses from fuseholders to bushings (*i.e.* Insulators), for which purpose steatite or Pyrex are also used.

Cotton and Silk Tapes find many applications in the winding of coils and other parts of electrical machines. These may either be pre-treated or impregnated after winding.

Press-board is made by a paper making process on a board-machine from suitably selected fibres, and is used chiefly for transformer insulation and for slot liners.

Laminated Boards are made by subjecting sheets of paper or fabric, bonded together by natural or synthetic resins to high pressure ; they are used for instrument and other panels, terminal boards, and end cheeks.—*R. A. Baynton, B.Sc., A.M.I.E.E.*

INSULATION: Heat. The theoretical considerations are dealt with under the heading Heat Loss, and a Table giving the conduction coefficients of a number of materials is printed in the article on Heating : (1) Theory. For the practical work of insulating, *see* Lagging.

INTERCEPTING CHAMBER AND INTERCEPTOR

By H. C. H. Shenton, F.R.San.I.

Describing the functions of the interceptor and its use in disconnecting the house drains from the sewer. The requirements for the intercepting chamber are outlined, with notes on the brickwork. For cast-iron interceptors and chambers, see the section immediately following. See Drains and Drainage : (I) Principles ; Garage Drain ; Inspection Chamber ; Manhole ; *also* Plate facing page 304.

Intercepting chamber is a term applied to the last inspection chamber on the main drain of a house system when it contains an intercepting trap (or "interceptor") for the exclusion of sewer air. The object of this chamber is to provide access to the trap for cleaning and inspection ; and also to make it possible to clean the connecting drain which runs between the interceptor and the sewer, by means of a rod passed through a cleaning eye on a special arm with which the trap is provided.

The intercepting chamber is generally placed at or near the boundary of the property, in order that the length of unventilated drain between the trap and sewer may be as short as possible. The trap of the interceptor has a water seal.

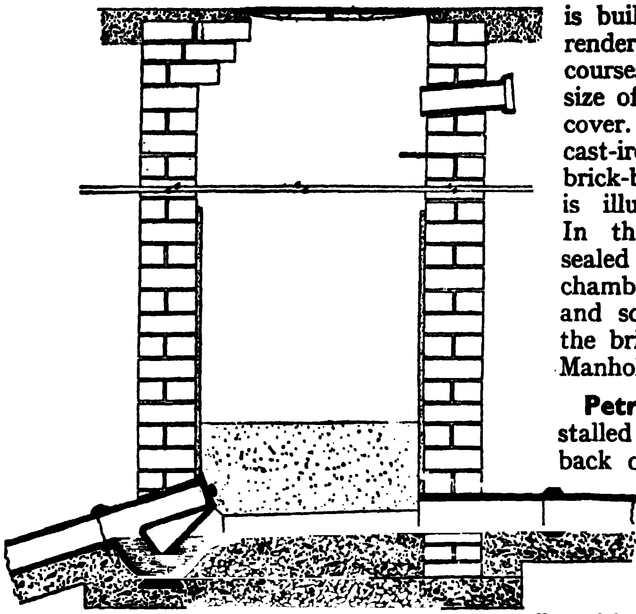
Disconnexion. Where house drains are connected to foul sewers or to cesspools it is essential to exclude foul gases which would otherwise find a free outlet from the house vent pipes ; but where good modern sewers exist the interceptor is often omitted in modern practice.• It is held that the trap may retain solid matters which may become septic and produce noxious odours, and that in the event of any large object finding its way into the drains, blockage is likely to occur at the trap. Such blockages, or partial blockages, often do occur when such objects as scrubbing brushes, sponges, cloths, etc., enter the house drains through w.c. traps ; and formerly solid blockages consisting of hairpins used to cause trouble in large establishments where many women were employed.

There is considerable danger when an intercepting trap is partially blocked, because in that case the house drains stand full of putrefying sewage which seeps away slowly through the trap ; since the drains still function after a fashion, the defect which may not be discovered for a considerable time. This is one of the reasons why intercepting chambers should be inspected periodically and why the traps should be kept clear.

Clearing Facilities. While it is desirable for flushing purposes to have a fall of three inches or more between the drain invert and the level of the water in the intercepting trap, this is not always possible, and traps are therefore used in which the inlet and outlet are at the same level. As the inlet to the trap is open in the intercepting chamber, all necessary clearing of material from the trap is done from the house side. There is a clearing arm, forming part of the interceptor, situated at a higher level and used for the passage of the rods and brushes when the drain beyond the interceptor is cleaned. On this arm an air-tight removable stopper is provided. Much trouble has been caused by the removal of such stoppers, which in the past were generally made of stoneware and were cemented in place, or provided with a bituminous joint.

Experience proved that when the stopper was removed for cleaning purposes it was often broken and not replaced ; also that it was sometimes forced out of place by gas pressure from the sewer, or was treated carelessly by workmen, with the result that while the sewer ventilated freely into the house drains the trap was blocked because the stopper had been allowed to fall into it. Thus in modern practice a galvanized iron or metal stopper is provided of such a type that it can be opened from the top of the chamber by means of a chain. This serves the double purpose of ensuring a tight joint and of providing an outlet for the escape of sewage in the event of the house system being flooded by blockage of the trap. The "Minimum Specification No. 111" (Inst. of Plumbers) recommends that the trap be set so that socket of rodding arm is inside finished face of manhole wall. *See* Fig. 16 on Plate *f.p.* 304.

Ventilation. The efficient ventilation of the interceptor chamber is important. As the interceptor is located at the lowest point on the drain an inlet of fresh air is necessary in order to provide thorough ventilation and prevent air pressure. A special fresh air inlet pipe is therefore provided, unless a well-ventilated branch drain enters the chamber in addition to the well-ventilated main drain.



INTERCEPTING CHAMBER. Fig. 1. Section through brick intercepting chamber showing interceptor and open half-section channel. (See also Drains, Plate 4.)

In some cases it is desirable to insert an interceptor between the rainwater drainage system and the house drain, or between the drains of a dwelling house and that of buildings on the same property containing particularly noxious wastes (such as the drainage of an infectious hospital). The interceptor in that case sometimes takes the form of a simple trap between two adjoining manholes, no cleaning eye or branch then being necessary because the trap and the inlet and outlet drains are accessible from both sides.

Brick Chambers. A typical brick chamber is shown in section by Fig. 1. It is built in 9 in. brickwork, cement rendered internally, the top three courses being oversailed to reduce the size of opening to take the manhole cover. The Fig. 3, p. 613, shows a cast-iron intercepting chamber in brick-built access chamber; another is illustrated in Fig. 4, p. 613. In this case the drain itself is sealed by the covers bolted on to chamber and interceptor respectively, and so is completely isolated from the brick pit or access chamber (*see* Manhole).

Petrol Interceptor. This is installed at garages in order to hold back oil and petrol which may enter the garage drain, and also retains mud washed from the car. For small establishments interception can be provided by a deep-seal trap gully with a perforated bucket (Fig. 2). The bucket is filled with coke to trap and hold back the oil and grease. When this becomes choked it can be burned or removed as trade refuse. On larger garages a three-chamber interceptor of a much more elaborate type is needed. This is described and illustrated under Garage Drains.

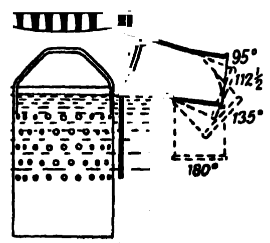


Fig. 2. Deep-seal trap gully as petrol interceptor: with perforated sediment pans, access cover inside, and heavy gratings.

INTERCEPTING CHAMBER AND INTERCEPTOR IN CAST-IRON

By D. Longden, M.R.San.I.

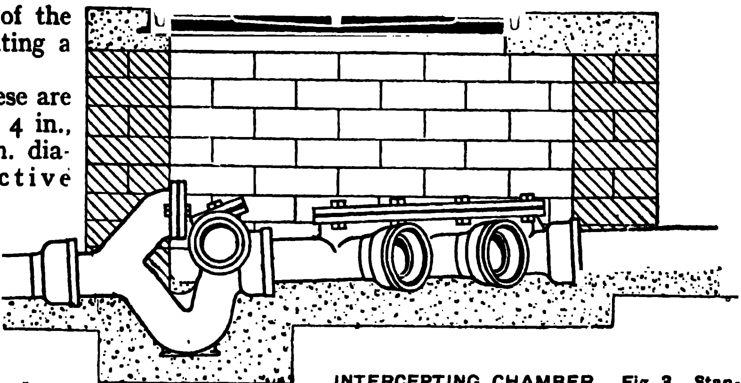
The intercepting chamber at the outfall of a drain may consist of the interceptor only, provided this has sufficient access and no branches have to be collected immediately behind it. The standard arrangement of an intercepting chamber is shown in Fig. 3; if the drain is suspended within the building the arrangement is the same, but the brickwork, concrete and manhole cover over are not required, of course.

The interceptor here shown is suitable if an interceptor only is used, since there is a clearing arm for the sewer connexion, a clearing plate for access to the trap and for rodding the drain, and in addition a vent socket (which may be cast on either side). This socket may be used to receive a ventilated drain, as most local authorities do not insist upon the use of an F.A.I. if two ventilated drains meet at the interceptor. The plates and washers are secured in the same way as the cover of an inspection chamber (*which see*).

Bottom Outlet Chamber. In conjunction with a standard trap this is frequently used for the intercepting chamber (Fig. 4). It has the advantage

of reducing the size of the manhole and facilitating a change of direction.

Interceptors. These are generally stocked in 4 in., 5 in., 6 in. and 9 in. diameters. The effective lengths are approximately: 4 in. dia.—21 in.; 5 in. dia.—23 in.; 6 in. dia.—25 in.; 9 in. dia.—33. The water seal is 2 in. in all sizes. Interceptors are shaped to cause as little restriction to the flow as possible, and to assist the flow there is a cascade or drop of 1 in. between inlet and outlet.



INTERCEPTING CHAMBER. Fig. 3. Standard access arrangement for an intercepting chamber. The trap is provided with a flanged clearing arm and cover. A separate cover gives access to the trap, and a socket is provided on the side for the connexion of a fresh-air inlet.

The interceptor shown by Fig. 3 is probably the best type, because of the cleaning facilities provided. By way of contrast, Fig. 5 shows a type frequently used but having many disadvantages. There is no access other than the rodding eye to the sewer connexion, and it is impossible to reach the base of the trap from an inspection chamber fixed behind. The clearing arm is fitted with a cast-iron stopper plate, bridle and gunmetal screw, which arrangement is inferior to the bolted cover shown in Fig. 4.

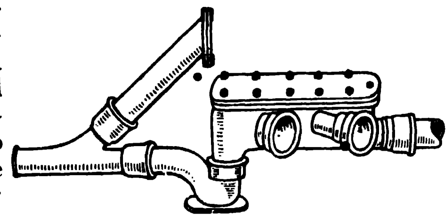


Fig. 4. C.-I. intercepting chamber with bottom outlet and bolted cover to clearing arm, often used with standard trap.

Connecting to Stoneware Channel. If a cast-iron interceptor is required to connect to a stoneware channel, that shown in Fig. 6 is suitable, since it has an inlet socket specially formed to receive the channel.

Releasing Stoppers. The clearing arm should be fitted with a brass or cast-iron clencher stopper (Fig. 8), with releasing chain secured near the top of the manhole. In the event of a stoppage in the interceptor and the consequent filling of the manhole, water can run away through the clearing arm when the stopper is released.

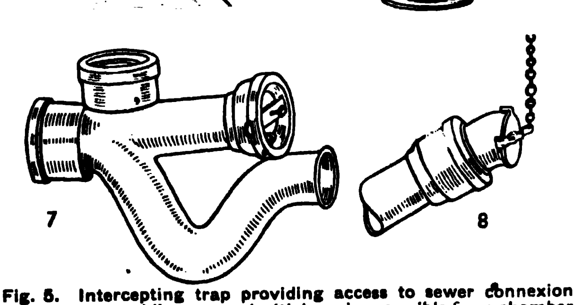


Fig. 5. Intercepting trap providing access to sewer connexion only through rodding eye and with base inaccessible from chamber behind. Fig. 6. C.-I. interceptor to take stoneware channel. Fig. 7. Interceptor with reverse clearing arm and top socket. Fig. 8. Clencher stopper with releasing chain for clearing arm.
Burn Bros., Ltd

Reverse Arm Interceptor. Interceptors are often fixed in places other than the outfall of the drain, notably to serve as master traps where rainwater or waste drains connect to soil drains. This type is known as the "reverse arm" interceptor (Fig. 7) because the clearing arm is in the reverse direction to the ordinary type. The interceptor illustrated has a top socket, which may be continued to the surface as a vent or to receive a gully inlet. If neither of these is required it may be plugged off and used for clearing only. These interceptors are made 4 in. and 6 in. only, and were much used by the Ministry of Works.

IRON: VARIETIES AND CHARACTERISTICS

By W. F. Chubb, Ph.D., B.Sc.

Cast-iron is dealt with in this work under its own heading, on account of its prime importance and the many applications to sanitary and domestic engineering. In the present contribution other varieties of the metal are reviewed, and the manufacturing processes briefly explained. *See also* Alloy ; Steel.

The exact date of discovery of iron is not known but the fact that it was a manufactured metal early in history is proved by the discovery of an iron-bladed dagger in Tutankhamen's tomb, a gift from a Hittite monarch. This means that iron was in use in 1360 B.C. and even earlier. Iron does not occur in nature in the metallic form except in the case of meteorites, which are alloys of iron with nickel and other metals. Its extraction from its ores involves heating the oxide ores of iron with carbon in the form of coke and this produces a very impure type of iron containing carbon and silicon as the chief impurities. This product is called " pig iron " and provides the basis for the manufacture of steel, cast-iron and wrought iron.

Characteristics. As iron is the most important and the most widely used of all the metals, details as to physical properties may be given. In the pure state—which may, however, only be realized by the use of very special methods of purification—iron is a grey metal of density approximately 7·8, its melting point is 1,530° C., and it may be made to boil in the electric furnace at a temperature of 2,450° C. It has a high tensile strength of about 20 tons/sq. in., is tough, and conducts heat and electricity, although its conductivity is at best only one-sixth to one-seventh that of pure copper.

Iron is malleable and can be bent to almost any desired shape both when hot and when cold. Impurities such as carbon and silicon have a pronounced influence on its properties. Thus the presence of carbon increases the hardness of iron and in addition conveys to it power of hardening when quenched in oil or water from a sufficiently high temperature. For instance, if pure iron is plunged into water from a temperature of 950° C. it will exhibit little or no increase in hardness, but if 1 per cent. of carbon be present the metal, when similarly treated, hardens very intensely and can then in fact be used as a tool for cutting steels and other materials in the lathe. Further increases in the carbon content induce brittleness, but at the same time the melting point is lowered very considerably, the metal is made very much more fluid, and is then suitable for casting purposes. It is then, in fact, cast-iron. Silicon added to iron increases the strength and hardness of the metal, but not to the same extent as carbon.

The chief disadvantages of iron as a material of construction are, firstly, that it is not sufficiently strong of itself for modern requirements, and secondly, that it is easily corroded or rusted by moist town atmospheres, particularly in manufacturing centres where the air may contain sulphurous gases. The material is therefore alloyed with other suitable metals such as nickel, chromium, tungsten, etc., for the purposes of increasing its strength, and these alloy additions also have beneficial influences upon its resistance to atmospheric corrosion. Owing to its strongly magnetic behaviour, however, iron is still used to a limited extent in the pure condition in laminated forms for the cores of electric transformers, although iron-nickel alloys are more generally preferred.

Iron is known to exist in three or four forms. At ordinary temperatures it is magnetic, but on heating it loses its magnetic properties at a fairly well-defined temperature of 765° C., so that above this temperature iron is non-magnetic. At about 900° C. it changes into yet a third form which has the remarkable property of dissolving carbon, whereas below the temperature mentioned iron will not dissolve more than a very limited amount of carbon. On heating further to about 1,400° C. it changes again into a fourth form.

Controversy has, however, existed amongst metallurgists as to the exact mechanism and meaning of these changes in its properties, for X-ray examination reveals only two crystalline forms of metallic iron. These changes are, of course, of little consequence to the plumbing and decorative trades, but they

are of very great importance to industry generally, since upon these changes in the constitution of iron is based modern theory and practice of hardening and tempering steels of all types.

To summarize, the chief physical properties of iron are given in the accompanying table :

Atomic weight	55·84
Chemical symbol ..	Fe
Specific gravity ..	7·8
Specific heat	0·119
Electrical conductivity	17 per cent.
Thermal conductivity	16 per cent.
Melting point	1,530° C.
Boiling point	2,450° C.
Brinell hardness ..	90
Tensile strength ..	20 tons/sq. in.
Elongation in 2 in. ..	40 per cent.

Wrought Iron. The starting point in the manufacture of wrought iron is pig iron, which in view of its method of production contains 3 to 4 per cent. of carbon, and silicon up to about 3 per cent. To bring pig iron to the more malleable form of wrought iron it is necessary to remove its carbon and reduce the silicon to very low percentages. This is achieved by heating the pig iron to bring it to a pasty condition, when it is worked into the form of balls on the hearth of a puddling furnace. In the process both the silicon and carbon are largely oxidized away and the balls are then subjected to hammering and squeezing under powerful presses in order to squeeze out a large proportion of the slag so formed. The whole of the slag is not, however, removed by this treatment, so that a certain amount of the slag remains in the iron and is elongated during the mechanical treatment, thus appearing in the finished product as streaks. It is in fact to the streaks of slag that the fibrous fracture of wrought iron is due.

Wrought iron is generally of very low carbon content, namely, 0·05 to 0·2 per cent., but occasionally a wrought iron may be found with a carbon content of up to 0·3 per cent. so that the material is somewhat variable in composition. The impurities are not uniformly distributed, and hence the mechanical properties are likely to vary in the same bar or sheet. A good quality wrought iron will nevertheless possess a tensile strength slightly superior to that of iron itself owing to the presence of the carbon as well as to the presence of manganese which is nearly always found. Owing to the slag streaks the ductility of wrought iron is lower than that of pure iron and hence typical figures are 22 tons/sq. in. for tensile strength, 22·5 per cent. for elongation, and about 55 per cent. for reduction of area.

Other impurities inevitably found in wrought iron are manganese, sulphur, and phosphorus. These are derived from the original ores used in the production of pig iron but in moderate amounts and if uniformly distributed they exert no harmful influences. The manganese content seldom exceeds 0·3 per cent. and is more usually about half that percentage, sulphur varies up to about 0·02 per cent. and the phosphorus content is always less than 0·15 per cent. The silicon percentage, reduced during the production of wrought iron, never exceeds 0·2 per cent. and thus a good quality wrought iron contains as a minimum at least 99 per cent. of metallic iron.

Owing to its ductility, wrought iron was at one time favoured for case-hardening purposes, but modern practice demands the use of specially made low-carbon steels. It is, however, still adopted in aircraft and automobile work to some extent as well as for a few electrical purposes, such as armature plates and cores, pole pieces for electro-magnets. Its uses are, nevertheless, diminishing and this is primarily due to its variations in properties, to its low crushing strength, and to the fact also that wrought irons not infrequently have been known to exhibit a certain brittleness of structure which cannot readily be removed by any simple annealing treatment. Wrought iron sheets are, of course, used extensively in the manufacture of furnace casings, boilers, tanks and similar equipments, particularly where a ferrous material easy to weld is required. Wrought iron has also been used in the past for large gates and in the form of strip for lift gates, but in these applications non-ferrous alloys combining high strength with lightness are now being increasingly adopted.

Malleable Iron. This material, which is very largely used for castings in the plumbing and decorative trades, is made in two varieties, namely, "Whiteheart" malleable and "Blackheart" malleable iron. (Microphotographs of these are printed in page 213.) The starting point is in each instance white iron, although there

are certain minor differences in the qualities of such iron selected for each process. Thus in the production of malleable iron the first step is to cast the article to pattern in white iron as produced from the cupola. In this condition the castings are hard and brittle and may indeed be easily broken if subjected to a shock. This brittleness is due to the fact that white iron is an alloy of iron with a high carbon content of about 3·5 per cent, but it differs from grey iron in that while the latter material is of approximately equal carbon content the carbon in white iron exists in the form of hard iron carbide, whereas the carbon in grey cast-iron is largely present in the form of soft graphite. This brittle iron carbide also gives to white iron a white fracture when broken, whereas the graphite of grey cast-iron conveys to the material a grey fracture.

As a structural material white iron is useless owing to its complete lack of ductility and hence a special treatment is necessary to render it ductile. This treatment takes the form of a prolonged annealing, and the treatment adopted depends upon the type of malleable iron to be produced. Thus, in making "Whiteheart" malleable iron, the white iron castings are heated for several days at a temperature of 950° C. and they are packed in annealing boxes, the castings being surrounded by an oxidizing material such as iron ore. The object is to burn out a large proportion of the carbon so that the product has a steely fracture with a rim of material which is practically carbon-free iron. In making "Blackheart" malleable iron, however, the annealing is undertaken at a lower temperature of 850° C. and in this method of annealing the white iron castings are packed in a non-oxidizing medium. In this instance the object is not to burn out the carbon but to decompose the hard carbides into ductile iron and soft graphite. The material so made shows when fractured a centre or heart which is black and a rim of practically carbon-free iron.

Of these two materials, the "Whiteheart" malleable iron has the higher strength, but the "Blackheart" malleable iron, though of slightly lower tensile properties, has the great advantage of higher ductility, and is indeed preferred when castings have to be machined in quantities. The following table gives typical properties for these two types of malleable iron.

	Blackheart	*Whiteheart*
Tensile strength	19 tons/sq. in.	22 tons/sq. in.
Elongation	15% minimum	7·5% minimum
Bend test	180 deg.	90° deg.

The term "malleable iron" is largely a misnomer, for it implies that the material can be shaped with a hammer. This is in fact not correct, although both types of malleable iron will withstand a certain amount of shock. They are indeed only malleable in the sense that they are not as brittle as either white iron or grey cast-iron.

In the plumbing and decorative trades and in household engineering, malleable iron is used extensively for brackets supporting water tanks, for joints and elbows in tubes for both gas and water supplies, for machined castings, as well as for the cases and fittings of motors, pumps, etc.

IRRIGATION TREATMENT. Method of purifying liquid sewage by distributing it over land. The liquid is run over or near the surface of the ground and is acted upon by innumerable bacteria in the top layers of the soil. These organisms bring about the oxidization of the putrescible organic matter, converting the latter into stable compounds. The process is described in the article on Sewage Treatment: (1).

JOINT AND JOINTING: of Cables. A joint, in electrical terminology, is an artificial junction, mechanical and electrical, between two or more conductors together with the insulation applied to that junction and the protective sleeving, if any. The requisites of a good joint are perfect electrical contact and mechanical strength.

I.E.E. Regulations. The I.E.E. Regulations for the Electrical Equipment of Buildings lay down the following rules for Jointing (Regulations 313 and 605):

Connexions between cables other than flexible cords shall be made either by soldered joints or by mechanical connectors. Every joint shall be easily accessible and mechanically and electrically sound. The conductors shall be soldered together, a flux free from acid or other corrosive substance being employed, and the resistance of the soldered joints shall be not greater than that of an equivalent length of the largest conductor included in the joint.

With vulcanized rubber insulated cables the joint shall be lapped with rubber to a thickness not less than that of the dielectric, and with waterproof protecting tapes so as to render it

moisture proof; and if the cable be sheathed with tough rubber compound the joint shall be enclosed in a joint box, the protective covering being maintained up to a point within such box.

Connexions between cables and flexible cords shall in every case be made by mechanical connectors shrouded in non-ignitable insulating material contained within suitable receptacles, which in the case of lamp fittings may form part of such fittings, and which, if not on the surface of the wall or ceiling, shall be non-ignitable.

Making Joints. When making a joint the first thing to do is to bare as much of the conductor as is required for the joint by removing the existing insulation with a sharp knife, taking care not to nick the conductor. The conductor must next be thoroughly cleaned by scraping with a blunt knife or similar instrument. Where there is more than one conductor every exposed part of every conductor must be cleaned in this way, not just the parts that are readily accessible without unravelling the conductors. The simplest joint for small single conductors is the "Britannia" joint. This is made by overlapping the conductors and binding them tightly together with binding wire (tinned copper wire) of suitable gauge. The whole is then soldered solid.

Another simple joint for the same service is the "bellhanger" joint. This is made by twisting the two conductors round one another in a fairly open pitch and then finishing up each end with a close pitch. The centre portion is then soldered solid as before.

For stranded conductors of small cross section a "brush" joint may be used. This is made by untwisting the conductors for some way, opening them out to form a brush, and then twisting opposite conductors together, finally covering the joint with solder.

Scarf Joint. The most simple joint for larger single conductors is the scarf joint. This is made by cutting the ends of the conductors at an angle, butting them together, binding tightly with binding wire, and soldering. With single conductors a tee-joint is made by binding the conductor of one cable tightly round a bare portion of the other, and soldering; with stranded conductors, the strands of one conductor are straightened out, half are placed on one side of the main conductor, a section of which is bared, and half on the other. Both halves are then tightly bound round the main conductor and the whole joint soldered. Sometimes joints are made by clamping the conductors in mechanical connectors, without the use of solder.

Insulation. The joints in small cables may be insulated with rubber-tape. The joint should first be smeared with rubber solution and the tape then applied under tension, first in one direction and then in the other; finally the joint is coated with rubber solution. Two or more layers of waterproof tape (black "Empire" tape) are then applied. The joint may be finished with insulating varnish.

Small joints in dry situations and of a temporary nature may be insulated by lapping on two or more layers of Empire tape and finishing with adhesive tape. In all cases the joint insulation should overlap the cable insulation. *See also* Insulation.

The jointing of power cables and the use of joint boxes is highly skilled, specialized work, a discussion of which would be out of place in this work.—*R. A. Baynton, B.Sc., A.M.I.E.E.*

See Conduit; I.E.E. Regulations.

JOINTING COMPOUNDS. Used in making all types of joints on pipes used for the conveyance of gas, cold water, hot water and steam, such joints comprising screwed threaded joints, union and flanged joints. The actual function of the compound or whatever jointing material is used is to provide a filler, or a packing or gasket, according to the type of joint, so that when the joint is screwed or drawn tightly together it will not leak.

There are a number of proprietary jointing compounds manufactured, such as graphite or manganese, which may be used by itself, or in conjunction with other materials such as hemp or joint packing. The use of such compounds is claimed to be advantageous inasmuch as joints may be easily disconnected, because of the non-rusting and non-setting properties of the material. It is also claimed that in certain joints (such as screwed threaded joints) no other material is required. The use of hemp, however, in addition, may still be regarded as standard practice.

Red lead paint and tallow are other materials used as jointing compounds, both in conjunction with hemp. It is preferable to use red lead paint on joints of hot water, heating and steam pipes, and tallow for cold water pipes. It is not desirable to use red lead on pipes for the conveyance of drinking water.

Threaded Joints. In making screwed threaded joints the paint or compound is smeared on the thread before the hemp is wound on.

The hemp should be wound on in a right-hand direction, or in the same direction that the thread is made, so that when the spigot is screwed into the socket a certain amount of hemp will be retained in the joint. A common fault in making such joints is to wind too much hemp on the thread, in a careless manner, with the result that the hemp is pushed off instead of being retained. Threaded joints on gas pipes may be rendered gas-tight by simply painting the threads with jointing compound or paint before screwing together.

Rubber and Gasket Joints. The rust joint for plain ended spigot and socket pipes used in horticultural low pressure heating mains has been largely superseded by joints made with rubber rings and washers. This method enables a clean, sound and easily disconnected joint to be made.

The use of rubber rings has also superseded the old-fashioned method of bedding on boiler and cylinder manlids with red and white lead and hemp.

For flanged joints a suitable gasket is necessary; or, if the flanges have ground faces, a smearing of jointing compound may suffice. For the gasket, when used, one of the many packings that are marketed is suitable, either in conjunction with a jointing compound or not, according to the make of the gasket. The use of rubber rings and gaskets should be confined to cold water pipes, and to hot water pipes where the temperature of the water does not exceed 180 degrees.—*W. J. Woolgar, M.R.San.I.*

See Joints: (1), (2), (4) and (5).

JOINTS & JOINTING: (1) WIPED JOINTS TO LEAD PIPES

By Percy Manser, M.R.San.I., R.P.

This article describes the leading types of wiped joints (Section A) and gives clear instructions for executing them. Section B deals with solder, with instructions for testing it. In Section C instructions are given for the preparation of the various joints and the actual job of wiping. For joints in cast-iron pipes *see* the article beginning in page 629. For joints to copper and brass tube *see* Pipes: (3); for iron and steel pipe joints *see* Pipes (4) and (6). *See* also Solder.

Plumbers' wiped joints are those formed with molten solder, wiped with a "cloth" and used for connecting together (*a*) lead pipes, (*b*) lead pipes with brass, gunmetal, or other alloy fittings.

A. TYPES OF JOINT DESCRIBED

Wiped solder joints are of various kinds, according to the purpose they are to fulfil and the methods adopted for wiping them. In the main they consist of ***branch, flange, knuckle, taft, underhand*** and ***upright*** joints. The last two names can be applied to any joints according to the position in which they are fixed for wiping, so that one may get an upright branch, flange or taft joint as the case may be; but the underhand joint is recognized as a straight joint wiped when the pipe is horizontal, and an upright joint when the pipe is vertical.

Variation of these terms occurs in many instances, such as for joints on pipes fixed on the slope; but the angle of inclination determines whether the joint shall be wiped as an underhand, an upright or a combination of both methods.

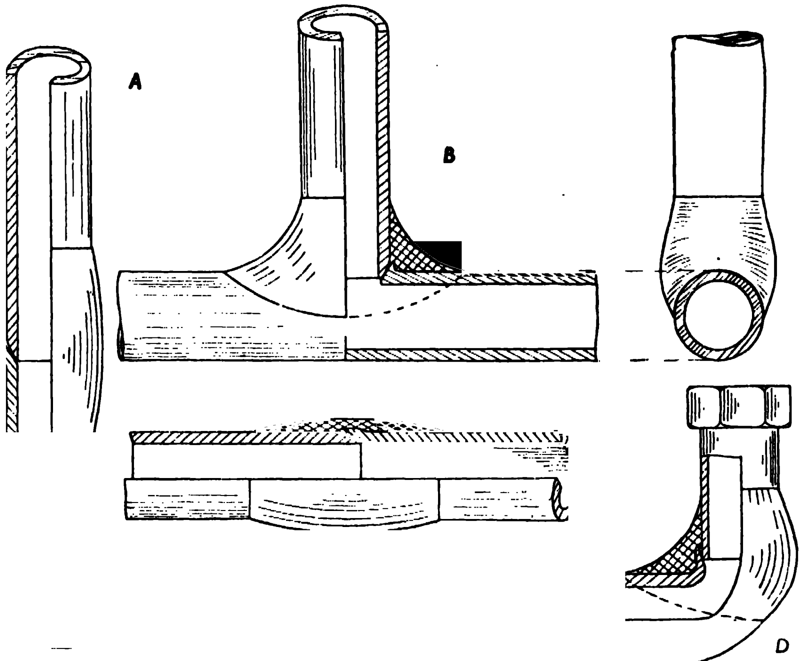
Branch Joint. The group of drawings in Fig. 1 show (in half sectional elevation) underhand, square branch, upright and knuckle joints. Branch joints vary in shape according to whether the pipes on which they occur are for conveying water, waste matter, or air. For water services they are of the square type and are seldom formed in any other way. For waste pipes, square branch joints should always be avoided, and if the pipes are properly arranged the joints must of necessity be of the raking type (as shown at A in Fig. 2), in which the branch pipe enters the main pipe in the direction of the flow of liquid.

Strictly speaking the branch and the main pipe should tend to form as near as possible a continuous easy bend, as shown at B, Fig. 2. To do this a slight bend must be made on the branch pipe (as at C, Fig. 2). This will allow the waste matter to be conducted freely into the main pipe without unduly impinging on the pipe wall opposite the branch, and thus breaking up the scouring action of the discharge.

Waste and Soil Pipes. These pipes should be as self-cleansing as it is possible to make them, and this can be accomplished by proper arrangement of the branches; the preparation and formation of the joints will automatically follow.

Branch joints for trap ventilation pipes should be on similar lines, as shown in Fig. 3.

Raking Branch Joints. There still appears some difficulty or misunderstanding in many instances of marking out raking branch joints, with the result shown in Fig. 4, giving an unbalanced joint which is more difficult to wipe and requires more solder than a properly shaped joint.



JOINTS : WIPED SOLDER. Fig. 1. Half-sectional elevations of joints: A, upright ; B, square branch ; C, underhand ; D, knuckle.

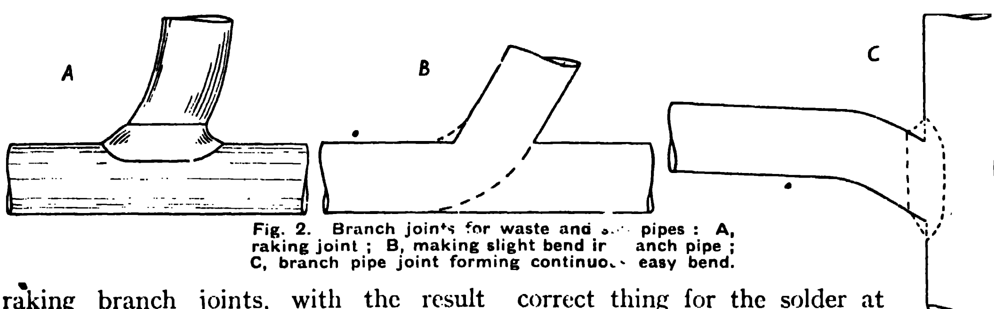


Fig. 2. Branch joints for waste and soil pipes : A, raking joint ; B, making slight bend in branch pipe ; C, branch pipe joint forming continuous easy bend.

Underhand and Upright Joints. These vary little except in length and, in many instances, in girth; in the latter respect it is usually considered the correct thing for the solder at the centre of the joint to be at least equal in thickness to the wall of the pipe, but many joints are made just bulky enough to cover the lead with a thin coating of solder. For joints on soil pipes the thickness of solder should exceed that of the pipe wall to obtain sufficient strength.

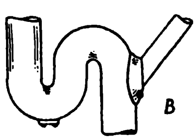


Fig. 3
A

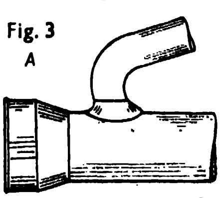


Fig. 4

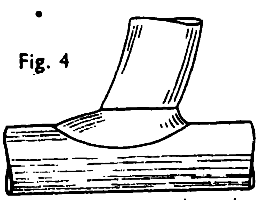
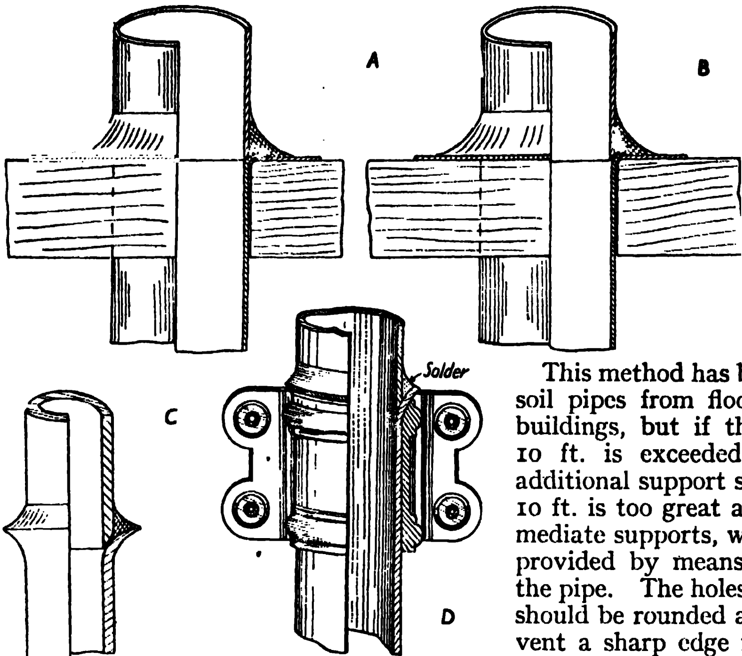


Fig. 3. Branch joints for trap vents : A, w.c. branch ; B, sink waste. Fig. 4. Badly shaped raking joint, difficult to wipe (see text).

Knuckle Joints. These vary a little in shape, and although useful in many positions and for many purposes, they are not suitable for pipes conveying waste matter.

Taft, Astragal and Block Joints. Other types of joints include those known respectively as taft, astragal and block or flange joints. All these are shown by the group of drawings in next page (Fig. 5, A, B, C, D).



JOINTS: WIPED SOLDER. Fig. 5. A, block flange: lead pipe turned over flat on to collar; B, block taft: lead pipe opened out in the form of a taft; C, taft or finger-wipe joint; D, half-section and elevation of pipe and socket forming astragal joint. (*Claughton Bros., Ltd.*)

The *taft* is often referred to as a finger wipe, and is sometimes permitted on overflow pipes, although it is frequently found on lead pipes of all descriptions, especially where repairs have been carried out. It is a simple method of joining pipes, requiring less skill and also much less solder than a properly wiped joint. The legitimate use of a finger wipe is in the formation of the astragal joint.

Astragals (from the Greek *astragalos*, the ankle bone) are the bands around the pipe or socket and are used in conjunction with a pair of cast lead tacks soldered to the back of the pipe. The tacks and astragals may be obtained cast in one piece, or they may be made separately. Sockets cast complete with astragals and tacks are also used, being soldered or burnt on to the pipe ends.

Block Joints. Used mainly where pipes are fixed in a recess or chase in a wall. The supporting blocks may be of stone or wood and are usually fixed at approximately 10 ft. centres (standard length of soil pipe). The lower length is placed in position through the block; a lead collar is prepared and slipped over the top end on to the block, and the pipe end tafted out as shown. This end is prepared for soldering; the next length with the lower end prepared is placed into position and a flange joint wiped. The operation is repeated on each length upward through the building.

This method has been adopted for fixing soil pipes from floor to floor in modern buildings, but if the standard length of 10 ft. is exceeded between the joints, additional support should be given. Even 10 ft. is too great a length without intermediate supports, which latter are usually provided by means of tacks soldered to the pipe. The holes in the blocks or floors should be rounded at the top edge to prevent a sharp edge forming when bossing over the flange on the pipe.

Brass-Lead Joints. Brass-to-lead connexions form a very large proportion of the wiped joints in plumbing, as they are used for practically every sanitary fitment when the pipes are of lead or a combination of iron and lead. In addition to the Knuckle Joint (Fig. 1) other types are illustrated by Fig. 6, and include:

(*a*) Cap and lining or union joint for connexions to union stopcocks, pillar taps, ball valves; flush pipes to waste preventors; traps to sinks, baths, lavatory basins, etc.

(*b*) Brass boss connexion to receive an ordinary screwed bib tap.

(*c*) Boiler screw (single nut) for connecting overflows or down service pipes to cisterns.

(*d*) Nipple union for connecting lead to iron pipe.

(*e*) Sleeve and thimble joints for making connexion between a pottery fitment and a cast-iron soil pipe when a lead branch pipe is used.

Lead to Iron, etc., Connexions. When lead pipe is to be connected to cast-iron soil or drain pipe, stoneware drain pipe or pottery fitments, a connecting piece of brass, copper, gunmetal or suitable alloy must intervene. A caulked lead joint cannot properly be made between a pipe of lead and a cast-iron socket or spigot; therefore a ferrule, sleeve or thimble must be

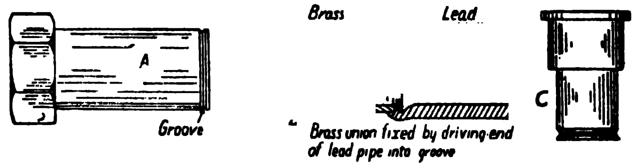


Fig. 7. A, B, fixing for brass union by grooving ; C, boss grooved.

soldered to the pipe to strengthen it and permit of caulking. A Portland cement joint cannot properly be made between lead pipe and a pottery spigot ; therefore a thimble, which is in effect a socket, is soldered to the lead to permit of proper jointing. Even if the lead were expanded sufficiently to form a collar or socket, lead and Portland cement in contact is bad practice and is not permitted.

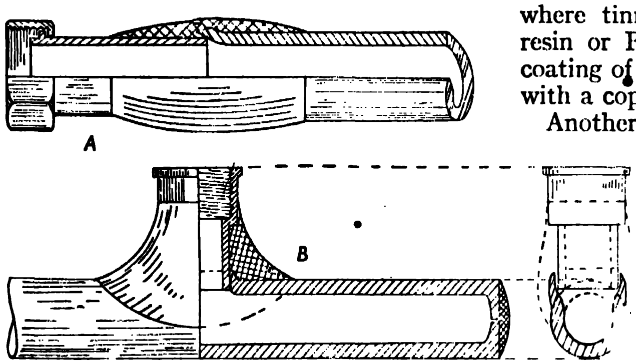
Sleeves. In fitting a sleeve or ferrule to lead, the correct method is for the sleeve to slip on the pipe so that the latter is continuous throughout without reduction of the bore (as shown by E, Fig. 6). In order for this to be done the sleeves should be large enough to pass easily over the pipe ; but what is usually classed as, say, a 4-in. sleeve measures a bare 4-in. inside. Obviously, this will not pass on to a 4-in. lead pipe. The result is that the lead pipe is opened and fitted on to the edge of the sleeve, and a joint wiped in a similar manner to that shown at B in Fig. 7. This takes more time to prepare and fix, and is a poor job. Sleeves of a proper size can be obtained.

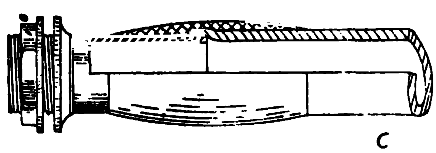
(In some districts it is customary to thread the lead through sleeve and turn it back over the open end of sleeve.)

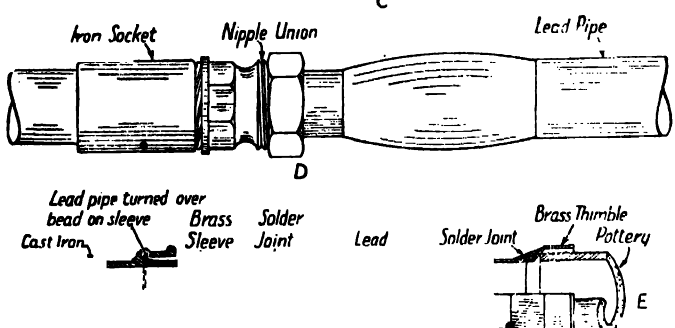
Brasswork in Jointing. What is generally known as plumber's brasswork includes gunmetal and other alloys, but fittings are here referred to as brass. To prepare brasswork for joint wiping it is necessary first to tin the surface which is to be within the joint. The fitting is filed where tinning is required, flux such as resin or Fluxite paste is applied, and a coating of fine (tinman's) solder is applied with a copper bit.

Another method often adopted is to smear the filed portion with Fluxite, heat the brass in a blow-lamp flame, apply solder direct from the stick and wipe the tinned surface with a piece of rag. To tin brasswork by coating with flux and dipping it into a pot of wiping solder is bad practice, especially if the brasswork contains zinc, as zinc is " poison " to solder. Brass filings must not be allowed to get into the solder pot.

Grooving and Splints. To fix brasswork to lead it is now the general practice to slot or groove the fitting by filing a groove as close to the end as possible (as shown at A, Fig. 7). The lead is then " closed " into this groove by a small hammer (B, Fig. 7). For small pipes this gives sufficient fixing for the joint to be wiped ; but on pipes of 1½ in. or 2 in. and upwards it is usual to " burn " the lead to the brasswork. A fairly hot copper bit is used, flux is applied to the





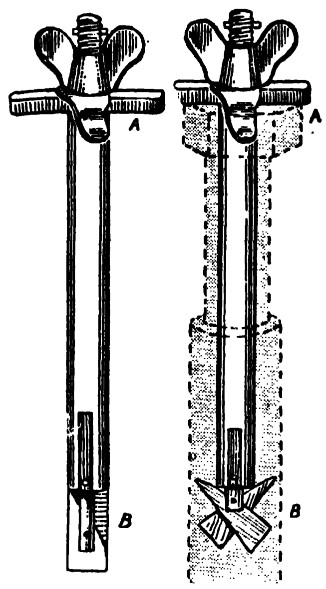


JOINTS : WIPED SOLDER. Fig. 6. A, cap and lining to lead ; B (left), half-sectional elevation of branch joint to brass boss and (right) transverse section through soldered stop end, showing outline of joint ; C, boiler screw for tank connexion ; D, lead to iron connexion ; E, application of solder joints for lead connexion between pottery and c.-i. pipe without reduction of bore.

lead and the edge of the pipe is fused to the tinning of the brasswork. If properly done this gives a secure fixing.

An alternative to grooving is to use wood splints; these are thin strips of straight-grained wood bunched together and passed through the brasswork in sufficient quantity to give a good push-in fit to both the brass and the lead pipe. This holds the brass in position while the joint is wiped, after which the splints are withdrawn.

Another method for small pipes is to use a patent holder which has loose jaws operated by a screw spindle; these jaws grip the inner wall of the pipe and keep the brasswork in position for wiping (Fig. 8). For fixing a boss (C, Fig. 7) a groove is invariably used; but if fixing is required without grooving, a plug-stick must be securely fixed into the boss and the stick secured by steel points or wood struts and tie strings, or by using a patent joint and pipe clamp such as the "Footprint" type (Fig. 9). Much depends on the conditions prevailing as to the best type of fixing to adopt, especially when the joint must be made in situ.



JOINTS: WIPED SOLDER. Fig. 8. The "Burloc" fixing tool for straight joints in brasswork: spring clamp A holds cap, while fully expanded lever B grips inside of pipe ensuring rigidity.
(*Shelack Tool Works, Ltd.*)

B. THE WIPING SOLDER

The solder used for joint wiping is of the coarse variety, being composed of two parts lead and 1 part tin (with a melting point of 441° F.). Solder varies in quality; when the tin content is high it is referred to as being "fine," and when low it is termed "coarse." These terms are used by plumbers to denote the nature of the solder, as it is an indication as to how it will "work" when wiping joints. With good or bad samples the coarse condition may arise by overheating, as this destroys the tin; it is termed "burning" the solder. Therefore, a pot should never be heated to redness.

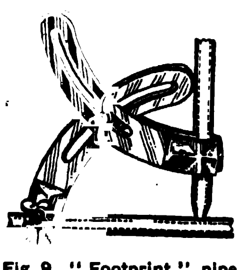


Fig 9. "Footprint" pipe clamp.
(*Shelack Tool Works, Ltd.*)

Coarseness may also arise through continuous use by picking up small quantities of lead from the pipes on which joints are made. When this condition becomes apparent it may be put right by the addition of pure block tin. If the solder is only slightly coarse, the addition of a few sticks of tinman's solder may suffice to put it right. Sometimes a pot of solder which is not working too well is improved by "fluxing" to clean it. A small quantity of powdered resin and a little tallow are well stirred into the solder, the residue on the surface being carefully skimmed off. But continuous skimming of the surface of molten solder should be avoided, as this impairs the tin content.

If solder is "fine," joint wiping must be carried out smartly, because setting at the edges of the joint will occur rapidly. Should the solder be too fine, it will be difficult to manipulate, and will give trouble by sticking to the wiping cloth, and also by the tin running and forming tears at the bottom edges or underside of the joint. Coarse solder allows more time for manipulation when wiping, but if allowed to become too coarse (*i.e.* short of tin) it will work sandy: the joints look pasty and dull, and in some cases will be porous and will "sweat" if subjected to water pressure.

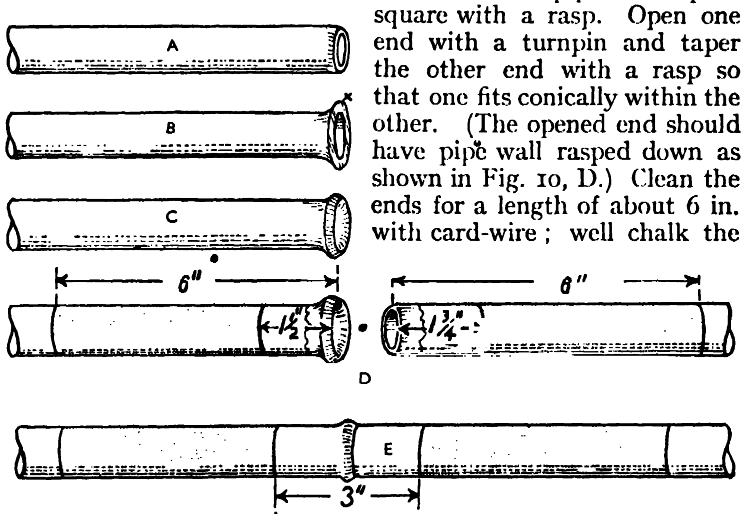
Poisoned solder is that into which zinc has become mixed, and in this condition it is of little use for joint wiping. To remedy this the solder should be heated and a handful of powdered sulphur stirred well into it. The zinc will combine with the sulphur and form a crust on the surface; this crust should be carefully removed. The solder must not be made too hot to carry out this cleansing process, or the sulphur will fail to "collect" the zinc. After the crust is removed the solder should be tested for quality, as it may be necessary to add a little tin.

Testing Solder. The usual test consists of pouring out two or three small discs of solder on to a cold surface such as stone, so that it cools rapidly, when the tin will appear as bright spots if sufficient in quantity. If short of tin the discs will appear dull and lifeless. Should there be any doubt as to quality, the best test is to prepare a joint, wipe it, and note how the solder works. Before using solder from a pot it should be well stirred to intermix the lead and tin because the lead, being of greater density than tin, sinks to the lower part of the pot. Several methods are used to test solder for temperature. It is mainly a matter of experience, and most plumbers can judge the heat by taking a ladle full of solder and holding the back of the hand a few inches above it. Others thrust a thin stick of dry wood into the solder and note to what extent it scorches; if too hot, scorching will occur rapidly. Another method is to fold a strip of paper stick-fashion, thrust it into the solder, leave a few seconds; if it bursts into flame quickly the solder is too hot, but if well scorched the heat is suitable for wiping.

A cold ladle should never be placed into a pot of hot solder, and when adding a fresh bar or bars of solder these should always be warmed before placing them into the molten mass. This is because steam is produced when a cold article is thrust into hot solder, owing to the moisture which is immediately formed. Serious injury may be caused by the hot solder which is thus blown out of the pot. *See also* Solder: (1) and (2). The latter deals with "frostiness" in solder.

C. PREPARATION AND WIPING

Correct preparation is important to obtain a proper joint (*i.e.* one sound and without a trace of solder inside the pipe). Points to bear in mind about wiping are:



JOINTS: WIPED SOLDER. Fig. 10. Underhand joint preparation: A, end tapered; B, end splaved; C, surplus rasped off; D, ends blacked and shaving lines marked; E, fitted for fixing and wiping.

Make sure the pipes fit well together so that solder cannot pass into them; see they are securely fixed; do not use solder too hot, or melting of pipe may occur; keep edges of joints hot during application of solder; make sure shaved portions are well "tinned" with solder before commencing to form the joint; work up a good heat so that, on commencing to "wipe," the solder works rather like soft butter; solder does not remain plastic for long, hence the need for smartness in manipulation.

Straight joints on pipes, whether upright or underhand, are prepared in the same way; the difference is in the application and manipulation of the solder.

To prepare a joint of this type proceed as follows: Make the pipe ends quite square with a rasp. Open one end with a turnpin and taper the other end with a rasp so that one fits conically within the other. (The opened end should have pipe wall rasped down as shown in Fig. 10, D.) Clean the ends for a length of about 6 in. with card-wire; well chalk the cleaned portions and coat with plumbers' black; when dry, mark off the length of joint with compasses or a joint gauge, the tapered end being marked longer to allow for entry into opened end. Using a shave-hook, scrape or "shave" the ends perfectly clean from the marking-off line. With a pocket-knife scrape clean the inside of the opened end. Smear the whole of the shaved portions and also part of the black with a flux of tallow. Fit the ends together and securely fix for wiping (*see* Fig. 10).

It should be mentioned that shaving the pipe before applying the black is sometimes preferred, because of the possible damage that may arise by a continuous straight cut along the marking line caused by heavy pressure on the shave-hook. When this method is adopted, the pipe is shaved haphazard to break up the

marks at each application of the shave-hook. A piece of paper is then folded round the pipe to act as a straight-edge and the black is applied (*see* Fig. 11).

Wiping. For underhand joints the solder is poured from the ladle, a moleskin cloth being held beneath the pipe to retain sufficient solder for the joint. Solder is gently poured over the whole length of the joint and well beyond on to the soiled portion, to heat the pipe ; and as pouring continues the cloth is used to lift the solder upwards to the top and work it round the pipe effectually to " tin " the shaved portion. When the solder is sufficiently plastic and in sufficient quantity the cloth is used to mould it roughly to shape, at the same time clearing the edges of surplus solder by pressure on the cloth with the first and fourth fingers.

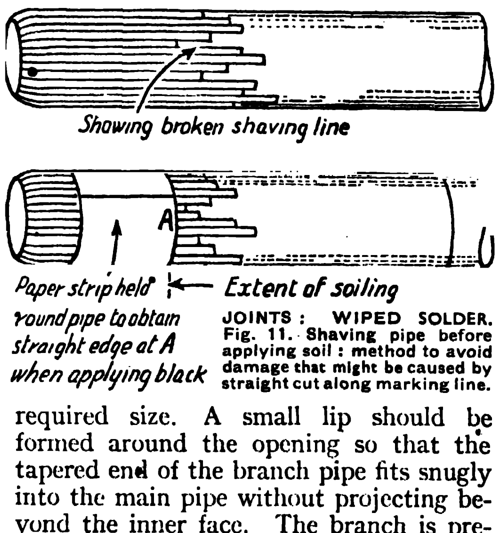
The cloth should then be gently but firmly passed right round the joint in one direction, thus bringing with it a surplus rib of solder the length of the joint. This rib is removed by gently drawing a " drag-off " along the joint. This appliance may be a strip of moleskin, bed-ticking or other suitable material. The drag-off operation is usually made at the back of the joint so as not to spoil the appearance.

For branch knuckle and upright joints the solder is " splashed "—lifted in small quantities from the ladle on to the joint by the splash stick and well on to the soiled portions to raise the heat. As splashing continues the solder falls on to the catch paper or into the collar in sufficient quantity to remain plastic, and is picked up by the splash stick and built up round the joint. When the solder is at the correct heat the cloth is taken in one hand and the splash stick in the other ; solder is picked up from the paper with the stick, placed on the joint and the cloth used to mould the joint and wipe it. With branch and upright joints the top edge cools quickly, and must be dealt with at the start.

In all wiping operations the movements must be smart.

Cloths. With regard to cloths, some plumbers use two for all sizes of underhand joints—a large one to catch the solder (called a catch cloth), and a smaller one to wipe the joint. Others use only one for small joints but two for large joints, owing to the amount of solder to be retained in order to get the " heat." These large cloths are called " blankets," and vary in size according to individual preference. Plumbers differ in the choice of cloths, and what may suit one may not suit another. Upright cloths are usually narrower from back to front than those for underhand joints. Branch cloths are, of course, much smaller, as they are manipulated in a totally different manner. Upright and underhand cloths should be of sufficient thickness to prevent the hands from getting overheated, and also to allow a properly shaped joint to be formed. A thin cloth will become too hot to hold comfortably, and will also cause injury to the hands in time. Further, such a cloth will become flabby and difficult to manipulate.

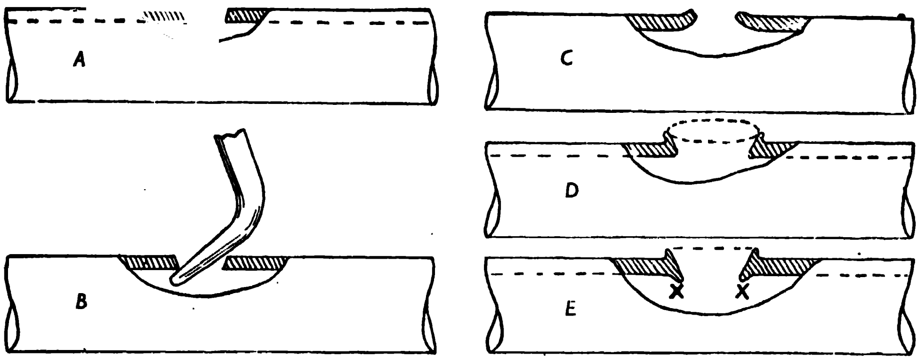
Small Branch Joints. A small hole is pierced in the main pipe with a gimlet or pipe opener and then enlarged with a small bent bolt and hammer to the



JOINTS : WIPED SOLDER. Fig. 11. Shaving pipe before applying soil : method to avoid damage that might be caused by straight cut along marking line.

required size. A small lip should be formed around the opening so that the tapered end of the branch pipe fits snugly into the main pipe without projecting beyond the inner face. The branch is prepared as described above for the taper pipe of an underhand joint (*see* Fig. 10). On each side of the opening in main pipe, for a distance of about 4 in., carry out cleaning, chalking and blacking as already described. The outline of the joint is marked with a pair of compasses having one leg supported in a scribing gauge as a centre.

There is no hard and fast rule as to the actual size of a branch joint of this type, but they should be made to look uniform with the underhand or upright joints on the same pipe. Styles vary according to the individual doing the job, but as a rule this uniformity is well maintained on good



JOINTS: WIPED SOLDER. Fig. 12. Preparation of small branch joint. A, small hole pierced; B, position of bent bolt in opening; C, opening partly formed; D, completely lipped opening formed without inside burrs; E, opening with burrs at X, X (see text).

class work. In forming the opening to receive the branch pipe, care must be taken to see that the " burr " is not worked up inside the pipe. If the bent bolt is of the right shape and size this may be avoided under normal conditions, but in awkward positions it is sometimes difficult to prevent, and should it occur it must be cut away with a pocket knife before fitting the joint together. For explanatory diagrams *see* Fig. 12.

Large Branch Joints. Large diameter pipes are first trued up by passing a mandrel through them to remove any indentations and to obtain an even bore throughout—before any preparation in the way of joints or tack fixings is commenced. In dealing with pipes of a substance equal to 6, 7, or 8 lb. sheet lead, when a branch is to be inserted it is important to form a good lip around the opening in the main pipe to receive the branch, so that when the joint is complete the end of the branch pipe is well clear of the inner wall of main pipe. To do this the pipe is cut in the form of a double keyhole, as shown at B, Fig. 13; the ends are worked up first by drawing the lead along each side, and by so doing a good lip should be formed. Once the ends are obtained, the sides are a simple matter. The opening is best commenced with a fair-sized bent bolt, and afterwards completed with a small hand dummy or a mallet

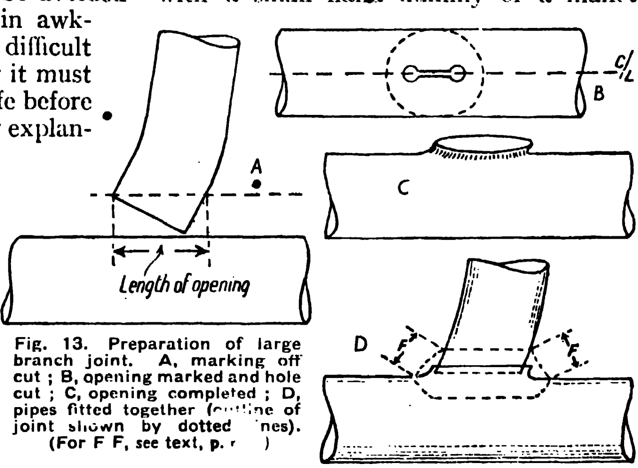


Fig. 13. Preparation of large branch joint. A, marking off cut; B, opening marked and hole cut; C, opening completed; D, pipes fitted together (outline of joint shown by dotted lines). (For F F, see text, p.)

and rounded piece of hardwood similar to a mandrel. To assist the operation the pipe may be heated. When complete the opening should be as shown at C, Fig. 13.

If the branch is to be at right angles with the main, the opening in the latter will, of course, be circular; but with a raking joint it will be more in the form of an ellipse. The marking off for the branch

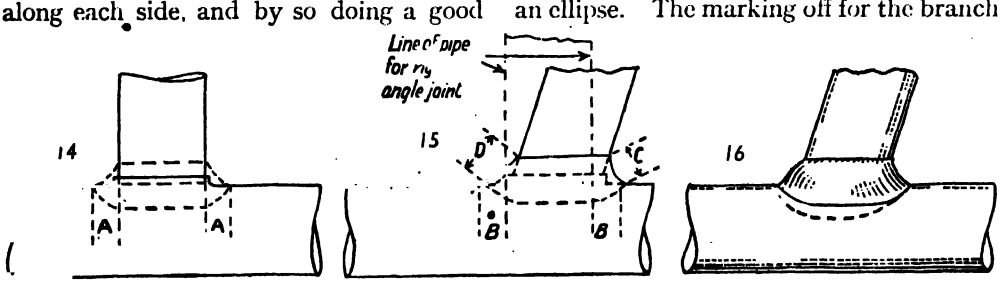
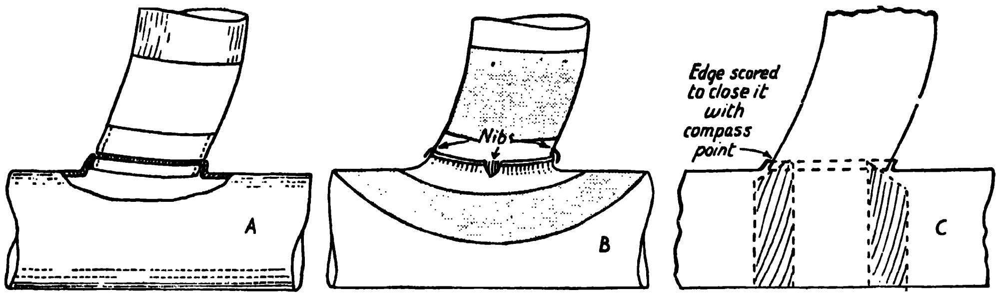


Fig. 14. Right-angle branch (for A, A, see text, p. 626). Fig. 15. Unbalanced joint (for lettering see text). Fig. 16. Balanced joint.



JOINTS : WIPED SOLDER. Fig. 17. Securing branch to main to prevent movement. A, fixing by grooving : part wall of main pipe cut away to show section ; B, three or four triangular nibs are cut in spigot and bent over lip of opening when fixing joint for wiping ; C, section showing wood supports.

is shown at A, Fig. 13, and also the length of opening required. How to mark out the shape of the joint is best explained by assuming it to be a right-angle branch as in Fig. 14, in which the lengths at *AA* are equal.

If the same distances are taken for the raking joint (as at *BB* in Fig. 15) and the correct shaving line marked on branch pipe, the shape of the joint will be as shown by firm lines in the diagram, with a short throat and long heel as *C* and *D* respectively (Fig. 15). But if the throat and heel are made of equal length by the marking shown in diagram D, at *FF* (Fig. 13), a balanced joint as shown in (Fig. 16) will result. It will be seen that the shaving on heel is very short and that in throat very much longer; and this varies according to the angle at which the branch enters.

The curves for the bottom edge of joint can be obtained with a pair of compasses and a scribing plate, and these curves can be joined by a short line parallel with the top edge. It is unnecessary to extend the shaving as indicated by dotted lines in Fig. 16, as it involves a waste of solder, is more difficult to wipe, and is unsightly.

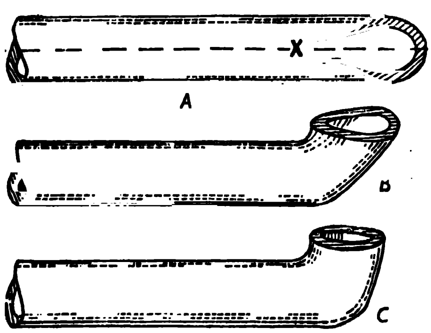


Fig. 18. Preparing pipe for knuckle joint. A, pipe cut : x = throat, y = heel ; B and C, stages in working up.

Securing Branch to Main to Prevent Movement. As the wall thickness of soil pipe is thin in comparison, various methods are used to secure the branch pipe and prevent it sinking into the opening when heat is applied for wiping.

Method 1. (Fig. 17, A). A groove is cut with the edge of a rasp around the pipe near the end ; the " lip " of the opening is then closed into the groove in a similar manner to that for securing brasswork.

Method 2. (Fig. 17, B). Two or four V-shaped cuts are made on the pipe end ; the pieces of lead are eased outwards to rest on the lip of opening and are afterwards closed down over the lip.

Method 3. (Fig. 17, C.) When practicable, two wood struts are used inside the pipe to support the branch, being afterwards removed from the end of main pipe. This is useful for bench work where the struts are accessible after completing the joint.

Note.—In any case, it is advisable to score the surfaces of the lead at the point of contact with a bradawl or the point of the compasses, to prevent solder seeping through during wiping.

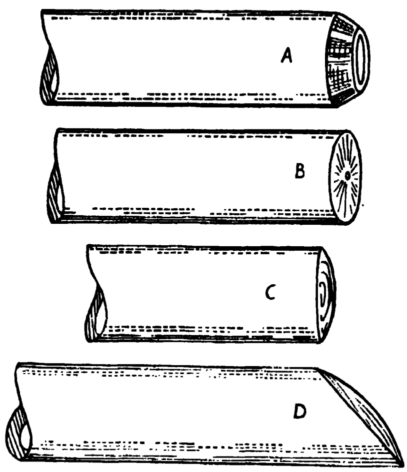
Knuckle Joint. To prepare this joint the pipe is usually cut as shown at A, Fig. 18, the throat *X* being worked up with a bent bolt and hammer, the heel *Y* bossed up with a small mallet so as to form a short knuckle bend, as shown in diagrams B and C, into which the brasswork is fixed by slotting, as already described (*see* pages 621-622). After cleaning and blacking, the outline of the joint can be marked out with compasses and scribing gauge as for a branch joint, the ends of the curves on the heel being joined up by an almost straight line.

This joint is useful for many purposes, especially for connecting water supplies to waste-preventing cisterns ; it makes a neat connexion, occupies little space and, unlike a branch joint, does not require a stop end.

Stop End. Where a branch joint is formed at the end of a supply pipe for

fixing a tap, a soldered stop end must be provided. These may be square (as at A–C, Fig. 19), or splayed, as at D. The end of the pipe is cut to suit either type and bevelled with a rasp; then it is bossed over to close it, shaved clean, and a convex solder end formed with the wiping cloth after the branch joint is wiped.

Another type is that which forms a stop end and a tack for fixing (*see* Fig. 20); the pipe end is cut to a long splay, bossed over and soldered so that a screw may be passed through for fixing purposes, as shown at A, B, C (Fig. 20).



JOINTS : WIPED SOLDER. Fig. 19. Soldered stop end. A, square end, pipe end tapered with rasp; B, end bossed flat with mallet; C, end soldered over. D, splayed end.

Fixing for Wiping. The usual method for securing pipes is to use steel points to which the pipes are tied. These points vary in length from 9 in. to 30 in., and are of ⅜-in. and ½-in. octagon steel. The ties should be of stout blind-cord, in lengths of about a yard, and having a loop at one end to facilitate tying.

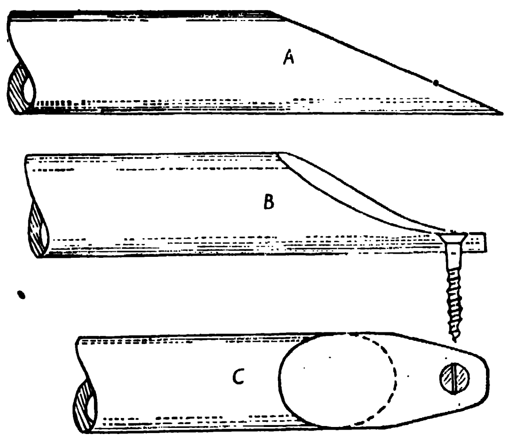


Fig. 20. Long splayed end to afford fixing. A, pipe cut to long splay; B and C, bossed over and soldered.

Where circumstances permit, steel points give a firm fixing; but occasions arise when they cannot be used, such as fixing to a tiled wall. In such cases fixing is usually effected by wood struts and ties, and it is a matter of ingenuity on the part of the plumber to overcome the difficulties which often crop up in this direction.

Patent clamps may be obtained for fixing the smaller diameter pipes clear of the wall for wiping purposes. Use can often be made of the plug-holes for the tacks, by driving the points into them for fixing purposes.

Catching Solder. After preparation and wiping, provision must be made for catching the surplus solder during the wiping operation. When at the bench this

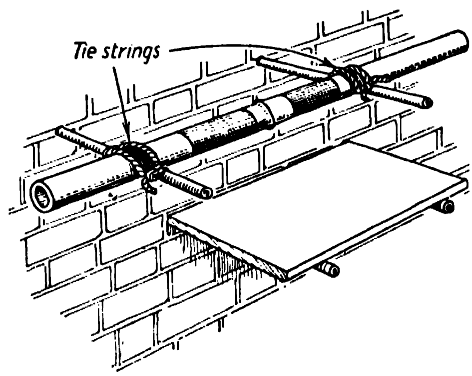


Fig. 21. Use of fixing points for securing pipes when jointing, and to support platform for catching solder.

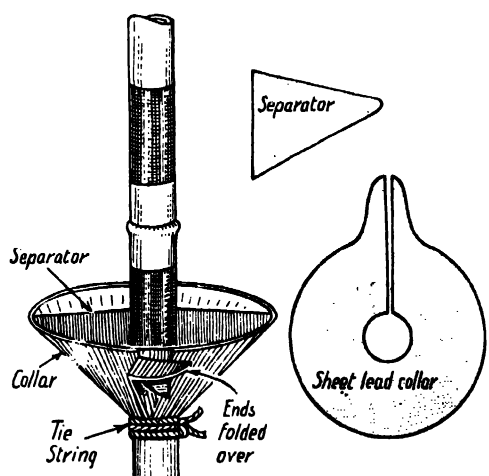
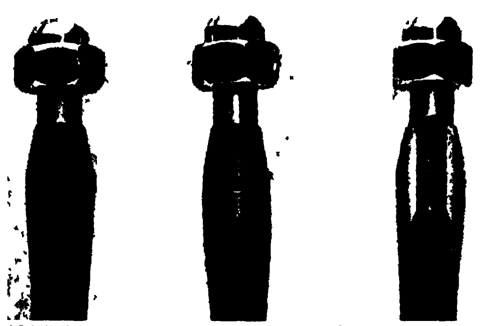


Fig. 22. Collar for catching solder during wiping of upright joints. Iron or wood separators are used as shown to render easy the removal of solder by "breaking" the ring formed around the pipe. Sheet lead collar should be well coated with plumber's black to prevent solder "tinning" and adhering to it.

is a simple matter, as a sheet or two of stout brown paper placed beneath the joint will suffice. An alternative is to use a thin sheet-iron tray, but paper possesses an advantage that it can be folded to suit varying conditions.

When working away from the bench, the methods vary according to conditions. For underhand or ordinary branch joints a small platform of wood to carry the paper and solder can be laid on steel fixing points driven into the wall (as in Fig. 21). For upright joints, either



JOINTS Fig. 23. "Staern" joint for all lead connexions to tailpieces, made with "Staern" liner which is inserted into the pipe; space between pipe and liner is then filled with very fine grain solder. See also Fig. 24.
Staern Engineering Co., Ltd

straight or branch, a lead collar is used, as in Fig. 22. As with fixing for wiping, when points cannot be used, other methods (such as struts, etc.) must be employed for supporting the platform.

Rolled Joints. This is a method used on the bench for connecting brass to lead on straight lengths of pipe. The joint is prepared in the usual way, the pipe being supported on blocks of wood so that it can be rolled backwards and forwards. Solder is poured on while the assistant steadies the pipe and, if necessary, gently rolls it forward or backward. As soon as the "heat" is obtained the plumber turns the pipe, while holding the cloth beneath the joint, and by a slight sideways movement he quickly moulds the joint, after which the joint is practically formed of itself by holding the cloth quite still, pressing on the outer edges with first and fourth fingers and, meanwhile, rolling the pipe backwards and forwards.

Overcast Joints. A process commonly called "washing," which consists of first wiping the joint and then using a large ladleful of rather cool solder and coating the whole of the joint with it. As soon as the coating is complete it is immediately removed and the joint smartly re-wiped with the cloth. Care must be taken not to use solder too hot, or the first joint will be melted and the washing process a failure. It must be just hot enough to permit of the surface of the joint being wiped over to give a smart finish.

One-Pipe System. Details of joints will be found under the heading of One-Pipe System (*which see*).

"Staern" Joint. This is a patented process embodying the use of a few special tools. Fittings with "Staern" liners are needed. The pipe is tapered, scraped and opened out, and the belled-out end is turned inwards (*see* Figs. 23-24). The liner is inserted, and fine solder introduced between pipe and liner by application of gentle heat.

FOLDING PLATE. In the Plate facing page 624 is given a series of photographic illustrations of branch and rolled joints, by courtesy of Tottenham Polytechnic.

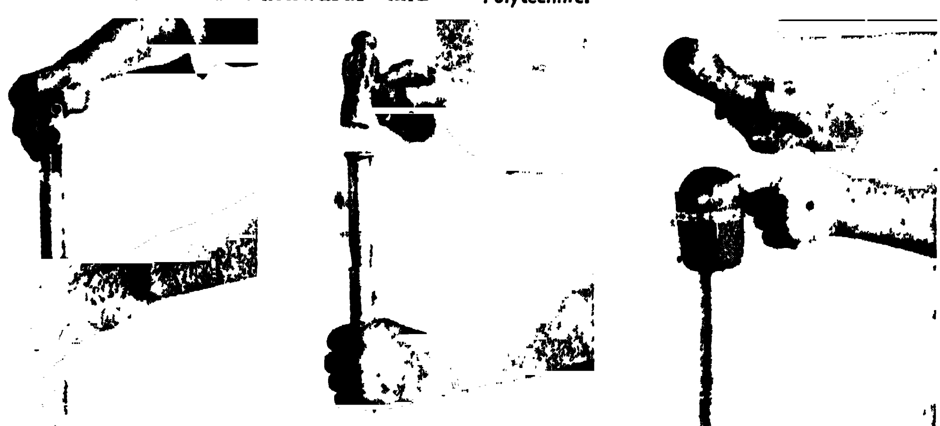


Fig. 24. Making the "Staern" joint: (left) inside of pipe is tapered to an edge with lead-cutter and scraped clean; (centre) pipe is opened to required shape by special splayed mandrel which is hammered in gently; (right) widened end of pipe is turned inwards by hollow wood cone which is tapped over it.

JOINTS AND JOINTING: (2) JOINTS TO CAST-IRON SOIL PIPES AND DRAINS

By W. J. Woolgar, M.R.San.I., R.P.

Instructions are here given for the jointing of cast-iron soil pipes and drain pipes, including cast-iron to earthenware joints. Yarning and caulking are explained, and also the use of lead wool. See One-Pipe System; Soil and Waste Pipes.

Cast-iron soil and drain pipes have a spigot-and-socket joint. The spigot of a length or a fitting is entered into the socket of the next length in each case. Two main operations constitute the making of the joint so formed after the spigot has been entered into the socket, the first operation being the yarning and the second caulking with lead.

Yarning. The importance of the yarning operation should be here stressed. Actually it consists of placing two or three turns of caulking yarn, or gaskin (*which see*), into the joint. The spigot should be centralized in the socket and the yarn staved in tightly with a yarning tool. The success of the joint, from a water-tight or air-tight point of view, depends to a certain extent upon proper yarning. Care should be taken that the yarn is not forced past the spigot end into the pipe. Where a length of pipe has to be cut previous to making the joint, it is desirable that a bead be shrunk on to the end. The bead on the end of the pipe assists in keeping the spigot central in the socket, and in preventing the entry of yarn into the pipe.

Caulking. In the second operation the remaining part of the annular space is filled with molten lead. The lead is poured in slightly higher than the top of the socket and to provide a wall around the top a ring of clay or other suitable material is used, or a specially made caulking ring. The lead so run into the space is then caulked down into the socket with caulking tools (*which see*), the protrusion of lead outside the socket allowing for the amount that is caulked into the joint. Properly made and sized caulking tools are important in this operation; care should be taken that the top of the lead is finished off neatly and level with the top of the collar.

Use of Lead Wool. Another method used in jointing cast-iron pipes is to substitute for the yarn a ring of lead wool. The lead wool is well staved into the annular space, which is then filled up with molten lead and caulked in as before described.

Where the presence of water inside or outside the pipe prevents or renders dangerous the use of molten lead (and also in cases where the pouring of lead is not possible), lead wool may be employed to caulk the whole of the joint. In this case each successive ring of wool is well staved or caulked into the space before the next ring is placed in. The operation is continued until the lead is level with the top of the collar as before.

Joints to Earthenware. In joining earthenware to cast-iron (as in the connexion between a water closet pan and a cast-iron soil pipe or drain), Portland cement, or Portland cement and sand, or red and white lead, are used as jointing materials. The outgo of the fitting should be placed centrally in the cast-iron

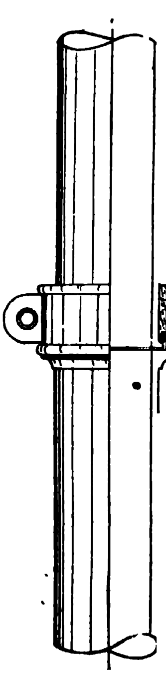


Fig. 1.

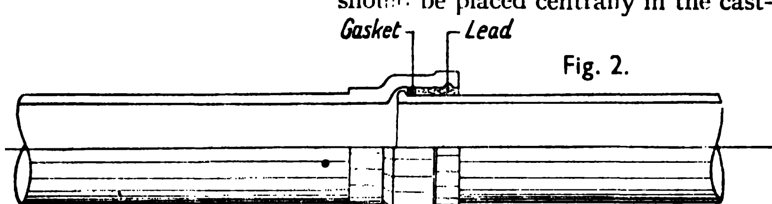
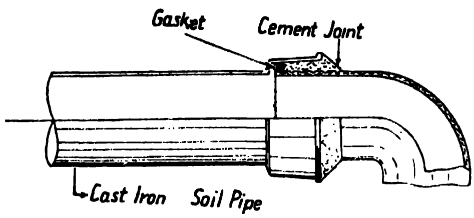


Fig. 2.

JOINTS : CAST-IRON PIPES. Figs. 1 and 2. Spigot-and-socket joints yarned with gaskin and caulked with molten lead : (left), c.-i., soil pipe; (right), c.-i., drain pipe.



JOINTS : CAST-IRON PIPES. Fig. 3. Earthenware-to-iron, joint made with ring of yarn and caulking of Portland cement.

socket and a complete ring of yarn placed in the joint to prevent the entry of jointing material into the pipe. The annular space should be filled with Portland cement (or Portland cement and sand in the proportion of two parts to one), the face of the joint being trowelled to a smooth surface.

In making a red and white lead joint the outgo of the fitting and the socket of the pipe should first be well painted. A ring of yarn is placed in the joint, and then alternately a bedding of red and white lead and yarn or hemp, until the jointing space is filled.

JOINTS AND JOINTING: (3) JOINTS TO STONEWARE AND CONCRETE DRAIN PIPES

The joints and jointing methods for stoneware and concrete drain pipes are discussed in the article on Drain Pipes: (1) earlier in this work, where will be found an account of the standard joints, with sectional diagrams, and also illustrations of a number of special or patent joints for stoneware pipes. Notes are included on the by-law requirements.

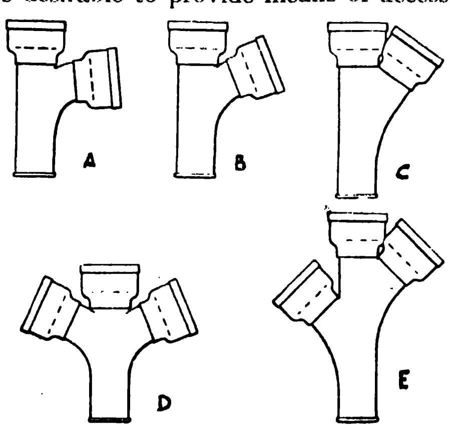
JOINTS AND JOINTING: (4) IRON & STEEL TUBE

The screwing and jointing of iron and steel pipes for hot water or heating systems is discussed under the heading Pipes: (6); information on the jointing of gas pipes is given in Pipes: (4), and on pipes for petrol, oil and compressed air lines in Pipes: (5). For other details about gas work *see* Gas: (3); Gas Fitting; Pipes: (4).

JOINTS & JOINTING: (5) COPPER & BRASS TUBE

The methods of jointing brass and copper tube are discussed under Capillary Joint; Compression Joint; and Pipes: (3). Here the reader will find ample information on the various types of joint for light-gauge tube, with diagrammatic illustrations and photographs. Pipes of larger dimensions are also dealt with.

JUNCTION : In Drain. Where the junction of two or more principal drains occurs, or where it is necessary to join a long branch drain to a main drain, it is desirable to provide means of access to the drain junction in the shape of an inspection chamber. In this case the actual junction of the drains will be in the form of open glazed channels; or, if the system is constructed wholly of cast-iron, a cast-iron inspection chamber will be provided.



JUNCTION. Fig. 1. C.-i. junctions to drain : A, 95°; B, 112½°; C, 145°; D and E, double junctions at 112° and 145°.
Cameron and Roberton, Ltd.

A junction pipe is used to connect two branch drains, or a short branch drain to a main drain. Junctions so used should be made with curved branches

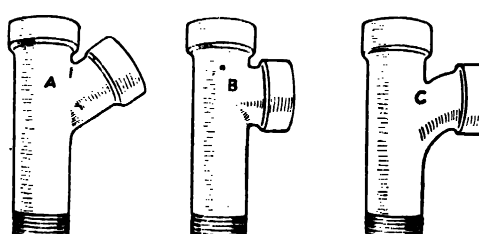
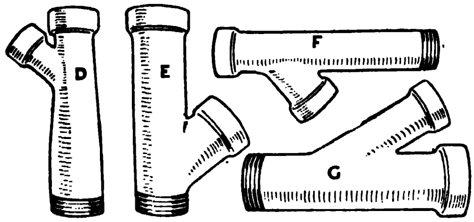


Fig. 2. Single junctions in stoneware : A, oblique; B, square ; C, curved.
John Knowles & Co., Ltd.

in order that the water flowing from the branch drain enters in the direction of the flow. The disadvantage of a junction piece is that access to the drain is not provided at this point;



JUNCTION. Fig. 3. Single junctions in stoneware: D, taper junction; E, special purpose oblique; F, reverse junction; G, "Floweesi" junction, 4 in. × 6 in. (*John Knowles & Co., Ltd.*)

for this reason short branch drains only should be connected in this manner and, if possible, means of access should be provided in the outgo of the gully, or at the foot of soil and vent pipes, as the case may be. Tee junctions (Fig. 2B) may be inserted on long lengths of drain, in order that lengths may be tested as the work proceeds. Tee junctions may

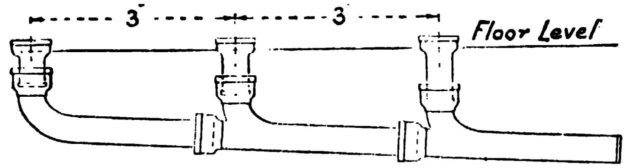


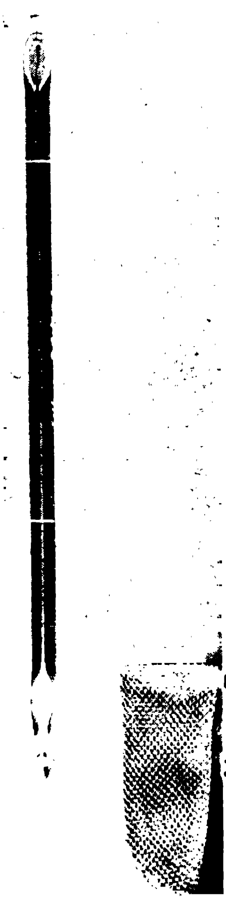
Fig. 4. Bends and junctions in c.-i. drain for range of w.c.'s at 3-ft. centres; also w.c. connectors with lengths suitable to drain fall; 4 in. × 4 in. and 92½°. *Cameron and Robertson, Ltd.*

also be used as a means of access in shallow drains, but are of not much use for rodding purposes.—*W. J. Woolgar, M.R.San.I.*

See Branch Drain; Drain Pipes; Inspection Chamber; Intercepting Chamber

KATA THERMOMETER. Instrument invented by Sir Leonard Hill and intended, as far as possible, to represent the human body and indicate the cooling effect of air surrounding it.

The air temperature, relative humidity and air movement are factors which play a most important part in forming conditions of comfort in rooms. A human body has an almost constant temperature of 98° F., and the various effects of atmospheric conditions surrounding the body include evaporation of moisture from the skin, providing a general cooling effect.



KATA THERMOMETER. Fig. 1. "Comfort" thermometer which measures cooling power of atmosphere in millicalories per sq. cm. per sec. Dry Kata measures air velocity, and loss by radiation and convection; wet Kata (with wet sheath over bulb) also measures cooling power by evaporation. Factor of each instrument, marked on stem, is divided by time in secs. that thermometer takes to cool from 100° to 95°. (*James J. Hicks*).

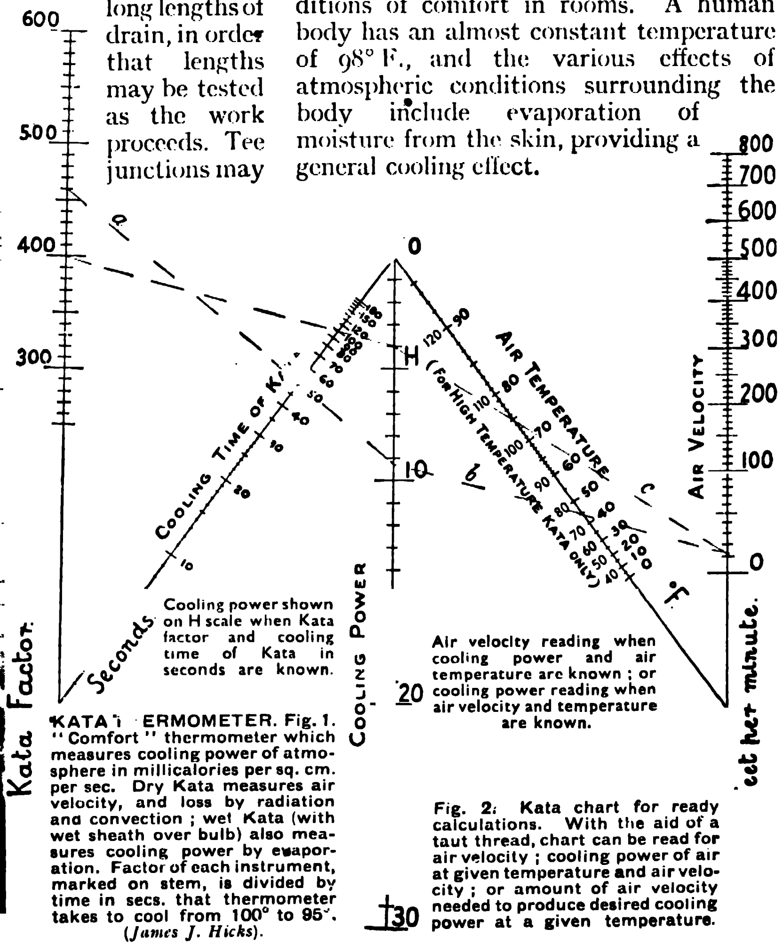


Fig. 2. Kata chart for ready calculations. With the aid of a taut thread, chart can be read for air velocity; cooling power of air at given temperature and air velocity; or amount of air velocity needed to produce desired cooling power at a given temperature.

Ordinary thermometers register the *temperature* of a substance (such as air). By wet and dry bulb thermometers suspended in the same air, the relative *humidity* may be calculated; or, given the wet and dry bulb temperatures, the relative humidity of the air may be read direct from a psychometric chart (*see* Humidity).

The Kata is in effect a thermometer with a large bulb. It is first raised to blood heat (98° F.) by immersion in warm water, and then a record is made of the time taken for the surrounding atmosphere to lower its reading through a certain number of degrees. Then a "finger-stall" of silk net is placed over the bulb and a wet-bulb reading is taken. Thus the cooling effect of the air on a human being can be gauged: the air conditions as regards temperature and relative humidity being known, a good test of comfort conditions can then be arrived at.

KILOVOLT. Practical unit of electric pressure for high voltage work. Equals 1,000 volts; abbreviated kV.

KILOWATT. Unit of electrical power. Equals 1,000 watts; also equals 1·34 horse-power (approximately). Abbreviated kW.

KILOWATT HOUR. Alternative name for Board of Trade Unit (B.T.U.). Equals current of 1,000 watts passing for one hour; in heating the equivalent is 3,415 B.Th.U. Unit of charge for electrical supply. Abbreviated kWh.

LAGGING: FOR HEAT INSULATION

By L. C. C. Rayner, A.I.E.C.

The chief insulating materials, with notes on methods of application to boilers and pipes. For information on the effect of lagging in reducing the loss of heat from pipes, etc. see Heating: (1); Heat Loss; Hot Water Supply: (1).

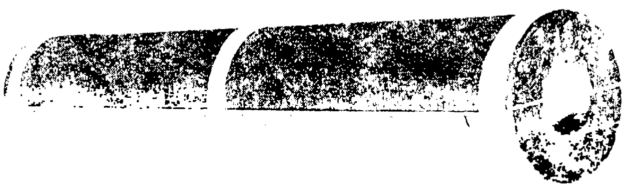
Lagging is material applied to hot surfaces to reduce as far as possible the heat given off by them, also called insulation. The attributes of good lagging are high efficiency, durability, resistance to knocks, lack of attraction for vermin, ease of application and good appearance. With high temperature surfaces the covering must resist the destructive action of the heat.

Efficiency is put first, as being the most important. No matter how many other good points lagging may have, if it is not efficient it does not serve its purpose. Indeed, in the case of poor lagging the heat emission from a hot surface is greater with it than without. If, for example, a 1-in. pipe is insulated 1½ in. thick (making the total diameter 4 in.), its circumference and consequently its radiating area will be increased to four times its original value. If the insulation reduces the surface temperature to only one quarter of its original value, the heat emission from the increased area will equal that from the bare pipe, and the insulation will be useless.

Efficiency of Insulation. The efficiency of lagging as applied to piping is the ratio of the heat given off per foot of bare piping minus the heat given off per foot of lagged piping, to the heat given off per foot of bare piping. Thus, if a foot of 2-in. pipe emits 120 B.Th.U. per hour when bare, and 30 B.Th.U. when lagged, the efficiency is 75 per cent. Efficiency of insulation is dealt with in detail in British Standards 1304 of 1946 and 1334 of 1947 covering "ready-to-fit" and pre-formed insulating materials (*see* p. 186B). Insulation depends on heat conductivity, the worst conductor being the best insulator. The external finish also plays a part. For best results it should be smooth and brightly polished, reducing radiation to a minimum. This is not often possible, but at least the surface may be smooth and painted with a light coloured paint. Black varnish is often used, but should be avoided, as black surfaces are the best radiators.

Some coverings have very poor efficiencies and do not repay the money invested in them. For this reason lagging materials should always be obtained from reputable firms.

Air is an extremely bad conductor, provided convection currents are not set up. Most lagging material, therefore, is of spongy texture, so that its mass is filled with minute air pockets. The greater the number of air pockets per cubic foot of material and the thinner the walls separating them, the better the lagging. The latest method of insulation,



LAGGING. Fig. 1. Plain sections of "Newtempheit" insulation for pipes; for reducing heat losses when temperatures are between 625° and 1,625° F. Appropriate sections of same insulation made for boilers, turbines, etc.; standard length 3 ft., thicknesses 1 in., 1½ in., and 2 in.
Newalls Insulation Co.

For this reason, and also because it has a higher efficiency, asbestos felt or asbestos blanket is to be preferred. Glass silk in sectional or strip form is widely used for pipes. Insulation is receiving close attention and new materials such as vermiculite (expanded mica) are being developed.

while utilizing air spaces, also employs rather a different principle. It consists in wrapping about three sheets of crumpled foil around the pipe the outside being protected by a steel casing. Here the foil, being bright and retaining its brightness, radiates a minimum of heat, acting somewhat similarly to the bright silvered surfaces of a vacuum flask and reflecting back the radiant heat.

Lagging Materials. The most common materials are diatomaceous earth (kieselguhr), asbestos mixtures, 85 per cent. magnesia (hydrated basic carbonate of magnesia mixed with asbestos fibre), hair felt, slag wool, and glass silk.

Diatomaceous earth, also known as fossil meal, is obtained from the Continent in the form of a grey powder, and is usually mixed with a certain amount of asbestos fibre to strengthen it. Mixed with water it is applied to the hot surface in the form of a paste. This is the most usual form of plastic covering. The asbestos adds to the efficiency but is more expensive.

Eighty-five per cent. magnesia is an extremely good insulator but very weak mechanically. It must always be protected on the outside with a layer of hard-setting compound composed of fossil meal, asbestos and plaster. The term 85 per cent. has nothing to do with the efficiency of the covering, but indicates that the material includes not less than that percentage of pure magnesia. Hair and wool felts are used for wrapping pipes, but have the disadvantage that they harbour vermin unless specially treated.

Boilers. Most manufacturers of sectional heating boilers provide jackets of galvanized steel for them. These have the advantage of resisting knocks from stoking tools. While they are new and shiny they are fairly efficient. To retain their efficiency they must be lined with asbestos slabs, or the boiler first covered with crumpled aluminium foil. Jackets are not obtainable for round boilers, which are best insulated with 85 per cent. magnesia applied in at least two layers to a thickness of 1½ in. This should be reinforced with wire netting of about 2-in. mesh applied to the last layer. The magnesia should be supercoated ½ in. thick with plastic asbestos trowelled to a smooth finish and painted two coats of light coloured heat-resisting paints.

Big boilers should have a wrapping of canvas outside the lagging, and be banded with brass, the total thickness being increased to 3 in. For large boilers having long and heavy stoking tools, a mild steel protection plate should be fitted over the lagging around the fire door. Cylinders and tanks are treated in a similar manner.

Lagging to Pipes. The most usual form of insulation for hot pipes which will be accessible at the completion of the work

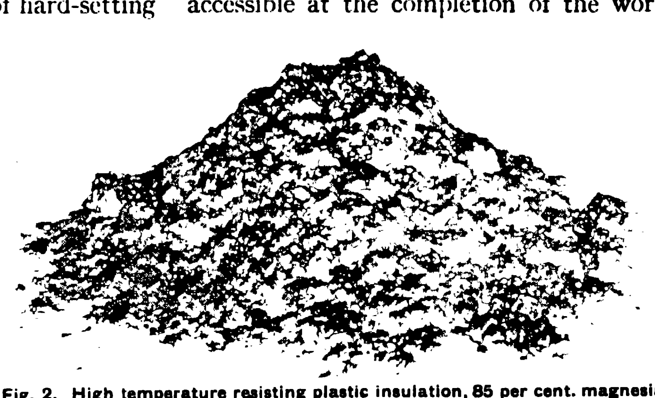
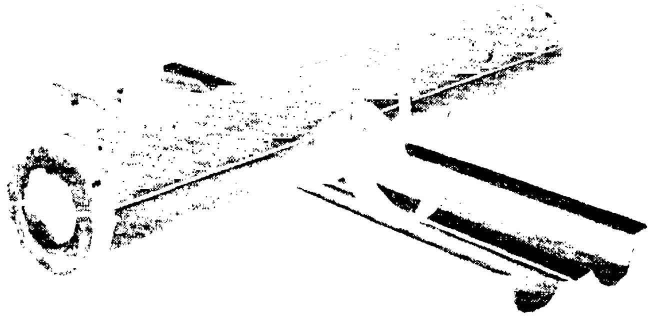


Fig. 2. High temperature resisting plastic insulation, 85 per cent. magnesia; covering capacity 1,700 sq. ft. per ton, applied 1 in. thick to flat surface; supplied as dry powder.

is plastic or sectional magnesia or asbestos and fossil meal. These plastic materials must be applied to hot pipes. Usually pipes up to and including 2-in. bore have lagging of 1½ in. thickness, and for those over 2-in. bore a total thickness of 2 in.

The final surface should be smooth and be painted two coats. Pipes in corridors or other situations, where they are likely to be kicked, should be wrapped with canvas neatly stitched. When pipes are fixed in ducts or chases they will probably be covered in before the work is completed. Here sectional covering should be applied. This takes the form of hollow cylinders usually 2 ft. or 3 ft. long, the internal diameter being made to suit different pipe diameters. It is made from plastic magnesia or asbestos cast in moulds, and sometimes from layers of corrugated paper. It is split longitudinally down the middle after being wrapped with hessian. The hessian is cut on one side and left intact on the other, so forming a hinge. In use the covering is opened about the hinge and put on the pipe. It is then closed and finally secured with thin brass straps.



LAGGING. *Fig. 3.* "Empire" sections for pipe lagging: 85 per cent. magnesia; all surfaces and edges covered by asbestos paper; 3 ft. long, ¾ in., 1 in., 1½ in. and 2 in. thick; ready-moulded bends, elbows, etc., also available; weight 12 lb. per cu. ft.; bands fixed at 18 in. centres. (*Newalls Insulation Co.*)

Where pipes are fixed under a wooden floor the main difficulty is that notching joists will be necessary. Also, boards must be protected from excessive heat which will warp or shrink them. The insulation should, therefore, be as thin and efficient as possible. The material best suiting these requirements is glass silk, which may be obtained in strips of any desired width.

Smoke Pipes. It is occasionally necessary to insulate a smoke pipe to prevent overheating of its surroundings. Plastic magnesia and asbestos or asbestos rope are the best material. They should be spaced away from the pipe metal to avoid burning.

LAMP: Electric. An incandescent lamp is one in which a conductor (known as the filament) enclosed in a glass envelope (or bulb) is raised to white heat (or luminescence) by the passage of an electric current. The only two filament materials in use to-day are carbon and tungsten. The majority of lamps on the market have tungsten filaments, but a few conservatively minded people stick to carbon filament lamps for special purposes (for instance, for use in situations where great resistance to mechanical shock is required, and to make up banks of resistance). There are now modern alternatives far more satisfactory.

Tungsten filament lamps used for domestic lighting are known as general service lighting lamps (G.S.L. for short), and reliable manufacturers make these to comply with British Standard 161; in addition to laying down the lamp manufacturing tolerances, this Standard

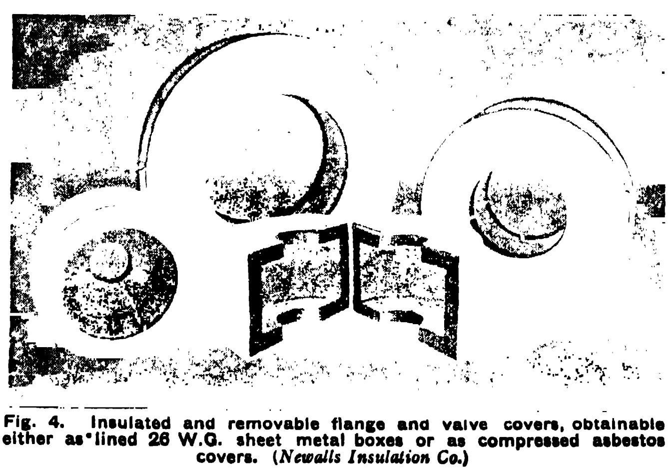


Fig. 4. Insulated and removable flange and valve covers, obtainable either as lined 26 W.G. sheet metal boxes or as compressed asbestos covers. (*Newalls Insulation Co.*)

specifies the maximum and minimum initial efficiencies for the various ratings, the minimum life, and the behaviour throughout life.

The rating of a lamp is the number of watts that it consumes at rated voltage. Both of these figures should be clearly marked on the bulb ; sometimes they are marked on the cap as well. Formerly lamps used to be denoted by candle-power, but the total light output of a lamp is now expressed in lumens, and its efficiency in lumens per watt.

Types of Incandescent Lamp. There are three main types of general service lamps : vacuum, gas-filled single coil and gas-filled coiled-coil. In the first the filament is contained in an evacuated glass bulb. This type is still the most efficient for ratings up to 40 watts, though some manufacturers have experimented with lamps containing a small proportion of a very rare, expensive gas with the object of improving the efficiency of these lower ratings. For ratings above 40 watts, gas-filled lamps have a better efficiency and the improvement in efficiency increases with the rating. In making a gas-filled lamp the bulb is evacuated and refilled with a mixture of argon and nitrogen (nitrogen alone for certain ratings).

The filament of the coiled-coil lamp is made by first winding the tungsten wire into a coil and then coiling this coil, thus concentrating the filament into a smaller space. This has the effect of improving the efficiency still further, by as much as 20 per cent. in some cases. At present coiled-coil lamps are made only in ratings up to 100 watts ; above this, gas-filled single-coil lamps are used.

At one time it was thought that coiled-coil lamps were going to prove unreliable and to have only a short life, but this has not in fact proved to be the case ; and coiled-coil lamps may be expected to reach the specified life of 1,000 hours.

Although some pieces of electrical apparatus are not affected by small changes in voltage, this does not apply to lamps. For efficient working it is essential that an electric lamp should run at its rated voltage. An increase in the voltage of 1 per cent. decreases the life of a lamp by 16 per cent., and a decrease in voltage of 1 per cent. decreases the light output by 4 per cent. The only occasion when it is permissible to under-run a lamp is when the variation in supply voltage is so large, in defiance of statutory regulations, that to run at rated voltage would lead to frequent burn-outs. The efficiency of a lamp decreases with use, and when it has run for 1,000 hours is only 75 per cent. of its initial value.

Gaseous Discharge Lamp. In this type the light source is an electric discharge between heated electrodes through a gaseous filling containing metallic vapour (mainly sodium or mercury) at high pressure. The tube, or bulb, in which the discharge occurs is itself enclosed in an evacuated glass jacket, the object of which is to assist in maintaining the high temperature required to vaporize the volatile metal. The lamps operate at mains voltage but, unlike incandescent lamps, require ancillary apparatus such as chokes and condensers in circuit. Mercury discharge lamps have a light output approximately three times, and sodium vapour lamps about five times, that of electric incandescent lamps. Originally the former were of a peculiar bluish-green hue, but the colour has since been improved ; the sodium lamps give an intense yellowish light. Initially mainly used for street and factory lighting, they are rapidly being superseded by fluorescent lamps for the latter purpose and to a lesser extent, but increasing extent, for the former.

Fluorescent Lamps. These are lamps in which ultra-violet radiations of a low-pressure mercury-vapour electric discharge are converted by a special fluorescent coating on the inside of the containing tube into visible light. There are five standard shades: daylight, natural, warm white, mellow and peach. Coloured lamps are also available. Lamps are manufactured in the following sizes and ratings : 15W, 1½ ft ; 20W, 2 ft. ; 30W, 3 ft. ; 40W, 2 ft. and 4 ft. ; 80W, 5 ft. ; 50-70W, 8 ft. 1 in. tube ; 75-125W, 8 ft. 1½ in. tube. The 15, 20, 30 and 40W ratings have bi-pin caps ; 80W and 75-125W, B.C. caps ; and 50-70W, special caps.

Ancillary apparatus, starting switch, choke and condensers, are built into the fitting, and installation presents no difficulty. They have a considerably higher light output than incandescent lamps of the same wattage, but first cost is higher.—*R. A. Baynton, B.Sc., A.M.I.E.E.*

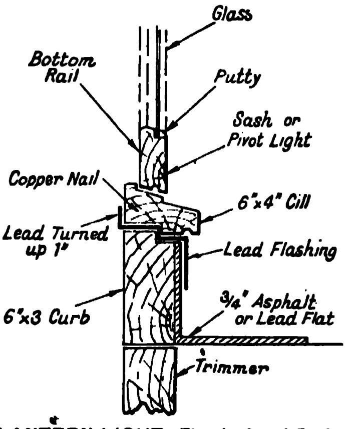
LANTERN LIGHTS: THE LEADWORK

By J. Malpass, M.R.San.I.

Notes on weatherings, flashings and other plumber's work to Lantern Lights. Practical hints are given on condensation troubles. The treatment of asphalt and lead covered roofs is discussed. **See Flashings ; Roofwork ; Skylight.**

A lantern light may be constructed on a flat roof or at the ridge of a pitched roof. It is used to give added ventilation and light, especially in the case of a flat roof, as it is difficult to roof-light rooms below this type by any other method. The lantern may be constructed of wood or steel, depending on the construction of the main roof.

A lantern light in steel does not call for any work from the plumber other than the glazing, as all weatherings are in steel. If constructed in wood it comprises (1) a wood curb, which is plated on the trimmer joist and allowed to project about 6 in. above the roof level ; (2) the framing, which is made in sections or constructed in the joiner's shop and delivered on the job complete. The framing, which rests on the curb, consists of vertical posts stub-tenoned into the sill, the posts being framed together by horizontal rails. The roof is usually of the pitched type, with either gable or hipped ends, and it is the practice to glaze where possible all sides and the roof. This may be done by means of wood glazing bars or by patent glazing.



LANTERN LIGHT. Fig. 1. Lead flashing to lantern light, covering upturn of asphalt or lead flat and continuing between members of curb and sill.

The sides of the lantern are used for ventilation purposes ; they may be constructed in the form of glass louvre lights, or have hinged frames, or frames which pivot on a pin fixed in the centre of the light. The latter type would be controlled from the floor for opening and shutting by means of a pulley and rope on a quadrant stay.

Condensation Troubles. A great deal of condensation takes place in a lantern light, owing to the warm, moisture-charged air from below condensing when it strikes the cold glass surface. On this account condensation grooves or gutters and outlets must be provided in the construction.

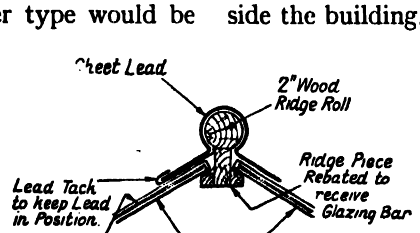


Fig. 2. Watertight joint between wood ridge and glass, made by lead-covered roll, with tack to hold lead in position.

It is difficult to indicate the particular type of provision needed, because it will depend greatly on the inside furnishings and fittings of the lantern light. If the pitch of a glass roof is not very great, condense drippings will fall, instead of running down the glass and escaping through the outlet provided. It is, therefore, advisable to design the roof with a pitch between 30 and 40 deg. so as to overcome this difficulty.

A triangular-shaped cut, tapering down to an outlet hole ⅜ in. wide, should be made in the bottom rail between each glazing bar on the roof lights ; this passage will allow the condense to pass safely outside the building. (In patent glazing it is the usual practice for the condense groove to be incorporated in the bar.)

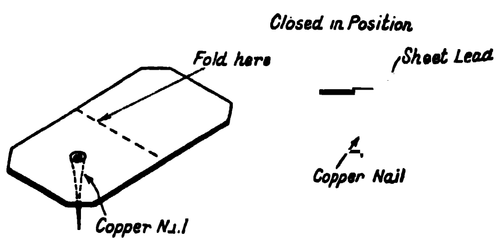


Fig. 3. Lead covering for copper nail to fix vertical leadwork on stiles or posts, shown open on left and closed on right.

For dealing with condense on the vertical lights, a lead gutter should be formed all round the lantern, and at various points ½-in. bore lead or copper pipes

should be taken to discharge in the outer atmosphere. (The size for outlet pipes may seem rather large, but it is recommended from practical experience. It is found that small-bore pipes soon become choked with dust and fluff, and fail to take the condense away.)

Flashings to Lantern Lights. It is the practice on large buildings to cover flat roofs with bitumastic asphalt. Here methods of making such roofs watertight will be described; the same methods may be employed for sheet lead coverings. Fig. 1 shows a lead flashing; it starts about 2 in. from the asphalt flat and continues up and between the various members of the wooden curb and wood sill, eventually being turned up

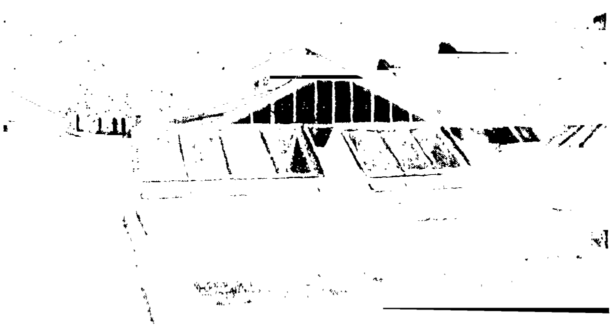
LANTERN LIGHT. Fig. 4. Lantern light built on pitched glass roof over drawing office, made watertight by means of lead soakers and flashing with double welts.

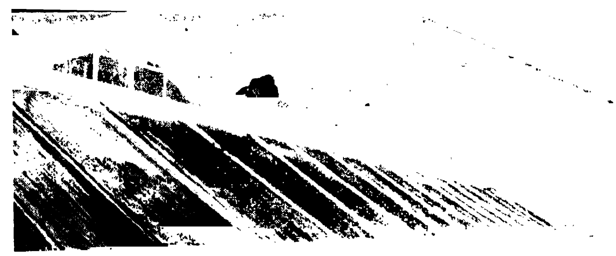
This type of roll may also be used where the glass meets the framing on the hips.

It is advisable to cover the stiles or posts of the lantern with sheet lead, as it is very often found that the timber cracks on drying, and rain will get in through them. The covering is quite a simple matter, the lead being simply turned round the post and sunk into the rebate at the sides which admit the opening lights. To support this vertical leadwork a piece of sheet lead 2 in. by 1 in. is speared by a copper tack and nailed to the face of the lead; it is then folded over to cover the nail head, as in Fig. 3.

The photograph given in Fig. 4 shows a lantern light fixed to a pitched roof of glass over a drawing office. Every light on the side elevation is pivoted to open, and is controlled from the floor by means of a quadrant stay.

Only the sides of the lantern light are glazed in this case. The roof and ends are covered with asbestos tiles of standard type, and the ends are made watertight to the main roof by means of a lead soaker. At the ridge the soaker is worked



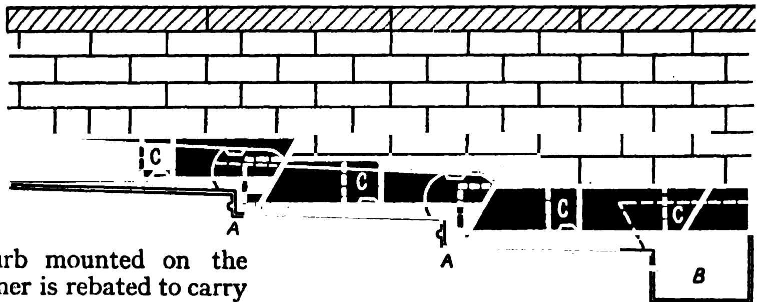


Figs. 5 and 6. Two aspects of lantern lights on flat roof over lavatories; leadwork details resemble those of Figs. 1 and 2.

behind the sill for a distance of 1 in. and copper nailed. Fig. 2 indicates the method of making a watertight joint between the wood ridge, and the edge of the glass; it consists of a wooden roll 2 in. in diameter planted on the ridge piece; the lead is covered over the roll and dressed down to the glass face for about 6 in.

to form a saddle, and at the bottom is worked round the post in a manner similar to that used for a chimney apron.

The bottom part of the framing consists of a wood curb mounted on the trimmer; this trimmer is rebated to carry the top ends of the patent glazing of the main roof. It will be noted that in this case the lantern light proper has not a wood sill, the pivoting lights closing on to the curb.



LAP IN LEAD ROOFING. Fig. 1. Longitudinal section of gutter and cesspool (B) between two parapet walls, with splash-laps (A) made in gutter lining at drips; side flashings (C) are lapped 3 in.

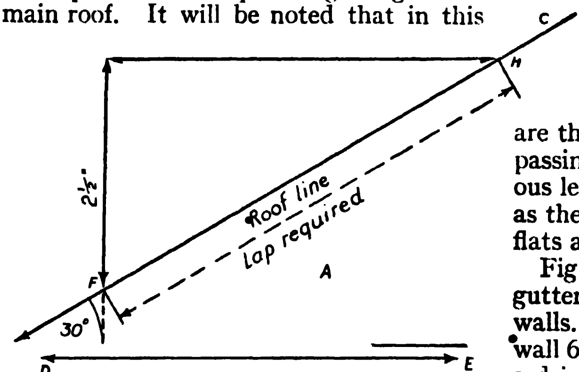


Fig. 2. Calculating length of laps for lead covering on low-pitched roof (see text p. 639 for explanation).

The lead flashing is taken up over the various members of the curb and turned down 1 in. inside the building; the bottom edge of the flashing is dressed down 6 in. on to the main roof glass surface. Owing to the exposed position of this range of lantern lights it was found advisable to use a double welt instead of just "passing" (*see* Lap) the lengths of lead flashings. Figs. 5 and 6 show two aspects of lantern lights to a flat roof over lavatory accommodation. The leadwork details are very similar to those shown in Figs. 1 and 2.

LAP: In Lead Roofing. A joint or passing formed between two pieces of lead in horizontal, sloping, or vertical positions. Laps (or passings, as they are sometimes called) are the parts of two pieces of sheet lead passing one over the other to form continuous lengths where running horizontal (*e.g.* as the lead turned up against the walls of flats and gutters).

Fig. 1 shows a longitudinal section of gutter and cesspool between two parapet walls. The gutters stand up against the wall 6 in., and are lapped at each length by a drip; the splash-lap at A in the diagram is usually 1½ in. wide, the drip being 2½ in. to 3 in. deep. The first gutter, starting from the cesspool B, is turned up at the drip and worked over the top edge about 1½ in. (the woodwork having been previously sunk to suit the thickness of the lead) and nailed down with copper nails. The next gutter is then laid and the lead worked over the drip and down on to the gutter below, forming the lap and splash-lap as required.

The same process must of course be repeated for each gutter. The flashings are then fixed: they are usually 7½ in. wide, thus allowing for 6 in. on face of wall to lap over the edge of gutter, and 1½ in. to turn into the brickwork joint. The flashings are usually cut across the sheet, being in 7-ft. lengths. For details of the undercloak and overcloak of the drip see Fig. 3.

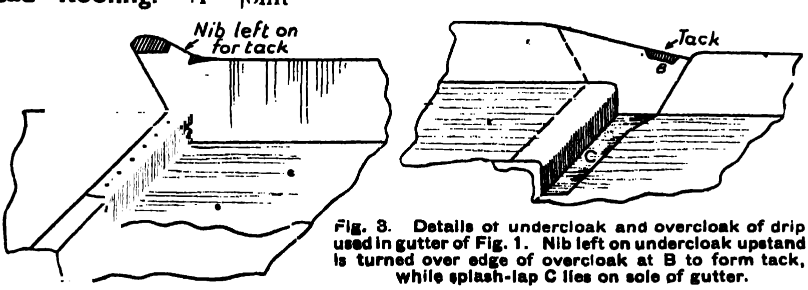
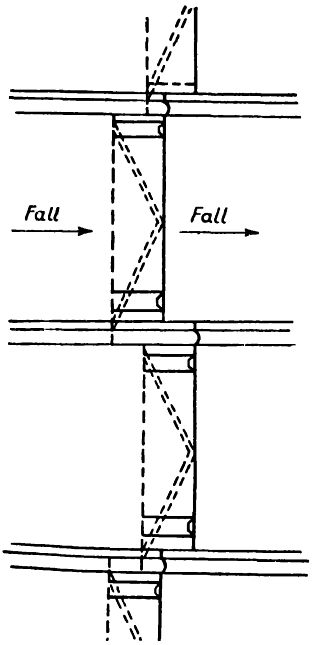


Fig. 3. Details of undercloak and overcloak of drip used in gutter of Fig. 1. Nib left on undercloak upstand is turned over edge of overcloak at B to form tack, while splash-lap C lies on sole of gutter.

The lead nib seen in the diagram is left on the turn-up against the wall in the undercloak of drip; the overcloak turn-up is then worked down into the drip, and where the lead passes or laps at the drip the nib is turned over and forms a tack, as shown at B. The splash lap C is shown at the bottom of drip, lying on sole of gutter. At each joint they are lapped 3 in., as shown at C.



LAP. Fig. 4. Plan of lead covered low-pitched roof having wood rolls; capillary grooves (dotted in) under laps (section of groove shown in Fig. 5).

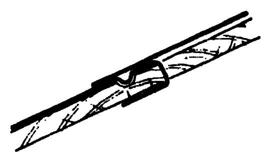


Fig. 5. Section of capillary groove on low-pitched lead-covered roof (see *also* Fig. 4); method of fixing sheet lead is indicated.

Low - Pitched Roofs. Roofs of low pitch covered with lead should be protected from capillary attraction at the lap. The length of lap required for any pitched roof is found by taking the least that would be allowed for a vertical drip, which is $2\frac{1}{2}$ in. Draw a line to represent the pitch of the roof (in this case assumed to be 30 deg. from the line D, E (Fig. 2 in page 638).

Draw a vertical line F, G; mark off on this line $2\frac{1}{2}$ in. From the point G draw a parallel line to the base D. E. cutting the line of the pitched roof B, C, at H. The length from F to H is the least length of lap that should be allowed.

Fig. 4 shows the plan of a lead covered low-pitched roof having wood rolls, indicating the arrangement of the laps and capillary grooves. These grooves are cut into the woodwork before the lead is laid, after which the undercloak piece of lead is chased into them by a chase wedge. Then the overcloak is laid, leaving it quite flat; care must be taken not to dress it into the grooves since an air space must be left to prevent the water creeping up under the lap.

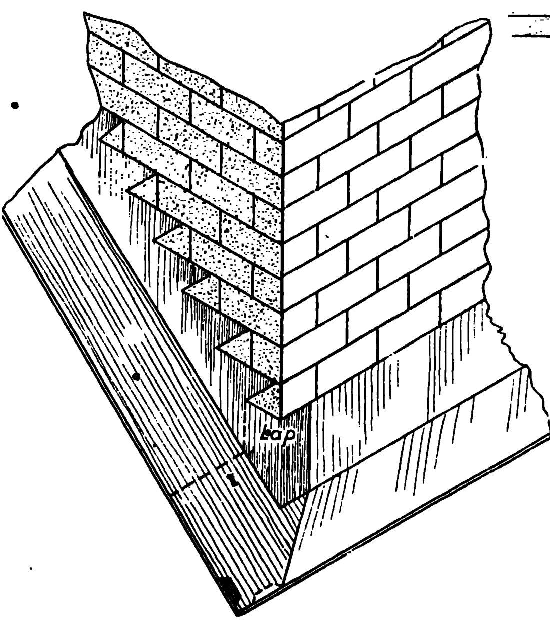


Fig. 6. Flashing at corner of chimney stack, showing lap of side step flashing over front apron.

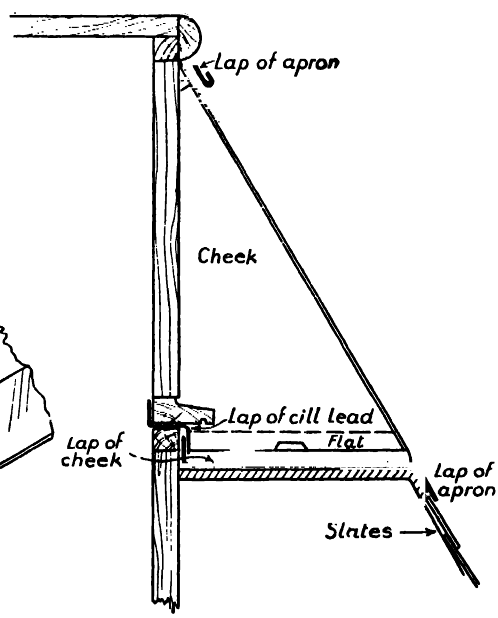
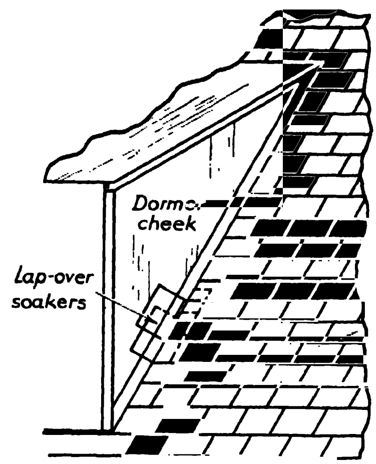


Fig. 7. Inverted dormer in section, showing lap of sill lead, cheek, and aprons.

The section of the capillary groove lap and method of fixing the sheet lead is seen in Fig. 5.

Dormer Details. The flashing at the corner of a chimney stack is shown by Fig. 6, and certain dormer details are explained by Figs. 7 and 8. Thus Fig. 7 indicates lap of sill lead which covers turn-up of lead flat to an inverted dormer, and also the turn-down to lap over the apron. Fig. 8 shows lap of dorme cheek covering the sheet lead soakers.—*H. Barrett, M.R.San.I.*



LAP. Fig. 8. Lap-over soakers against dormer cheek, used to make weather-tight joint to sloping roof.

LATENT HEAT. The quantity of heat absorbed by unit mass of a substance during a change of state without increase of temperature. Latent heat is of two kinds: (*a*) latent heat or fusion (or liquefaction) absorbed during a change from solid to liquid; (*b*) latent heat of evaporation (or vaporization), taken up during a change from a liquid to a gaseous state. "Unit mass" refers to weight, and in engineering the standard weight is 1 lb.

"Latent" means "hidden," and latent heat is hidden in the sense that, however much of it may be present in a substance, its existence cannot be detected by a temperature recording instrument such as a thermometer or pyrometer. The reason is that the energy (and heat is only a form of energy) has exhausted itself in either (*a*) changing a solid to a liquid, or (*b*) converting a liquid into a gas. It might be said that while this heat or energy was so occupied, it could not attend to its usual business of raising temperature—in short, that it could do only one job at a time. Actually, this seemingly lost heat is transformed to the mechanical energy necessary to bring about the desired change in the compactness of the molecular structure and volume of the substance. It may be noted, in passing, that heat which can be measured by a thermometer is known as "sensible heat," because it can be "sensed" by a recording instrument.

Ice, Water and Steam. The best example of both kinds of latent heat is seen in the continued application of heat to a 1 lb. block of ice, at a temperature of 32° F., contained in an open vessel. The block would absorb 144 British Thermal Units (the latent heat of fusion of ice) while the ice is melting, and during that time the temperature of both ice and water would remain constant of 32° F. Only when all the ice had melted would the temperature of the water commence to rise, at a rate of 1° F. for each B.Th.U. absorbed. This would continue until the water started to boil, at 212° F. At this point the temperature would again remain stationary until all the water had been changed to steam. It would be found that, to effect this second change of state, the water had absorbed 970·7 B.Th.U., and this without the slightest variation of temperature from 212° F. It is worthy of note that 970·7 B.Th.U./lb. (the latent heat of steam at atmospheric pressure) does not affect temperature during boiling, although, ordinarily, 1 B.Th.U. will raise the temperature of 1 lb. of water through 1° F., and 970 B.Th.U. would normally be sufficient to heat nearly 10 gal. through 10° F. Further heating would then raise the temperature of the steam above 212° F., so that it would become "superheated," but that could not happen while any water remained to be evaporated.

Steam Heating. It is this great store of latent heat in each pound of steam that is utilized in steam heating. Because 970·7 B.Th.U. have become latent during evaporation, each pound of steam must of necessity give up that quantity of heat during condensation, and before a pound of steam can again become a pound of water. That is, of course, what happens in steam heating. In contrast to the yield of only from 30 to 40 B.Th.U. from each pound of hot water circulated, the use of steam will provide nearly 1,000 B.Th.U. per pound of water evaporated in a boiler and allowed to condense to water at the points where heat is required.

Effect of Pressure. The pressure under which steam is generated has a

Table I.—Relation of Latent Heat of Steam to Pressure

Gauge Pressure lb./sq. in.	Boiling Point °F.	Above 32° F.		
		Sensible Heat B.Th.U per lb.	Latent Heat B.Th.U. per lb.	Total Heat B.Th.U. per lb.
(1)	(2)	(3)	(4)	(5)
* 0·0	212·0	180·0	970·7	1150·7
2·3	219·5	187·5	966·2	1153·7
5·3	228·0	196·1	961·0	1157·1
10·3	240·1	208·4	953·3	1161·7
15·3	250·3	218·8	946·7	1165·5
25·3	267·2	236·0	935·6	1171·6
100·3	338·1	309·2	884·3	1193·5

* Atmospheric pressure. Total heat = Sum of Columns 3 and 4.
See also Table *under* Steam: Properties.

considerable effect upon the latent heat of the steam. As pressure increases and boiling point rises, there is a progressive reduction in the quantity of latent heat required to evaporate the water; and, consequently, there is a proportionately lower emission of heat from the steam during condensation.

As will be seen from Table I, an unnecessarily high pressure in a steam heating boiler would mean less latent heat per pound of steam condensed, and correspondingly hotter condense water. Some of this latter heat is recovered when the water of condensation is cooled below its boiling point, as frequently happens in steam heated calorifiers. It is for this reason, as well as for greater safety and ease of operation, that the pressures used are always as low as possible, consistent with effective circulation of steam to the heat-distributing units. An extended Table is given later under the heading Steam: Properties.

Latent Heat of Fusion. All substances take up some quantity of latent heat when a change of state is brought about by heating. Table II shows the latent heat of fusion of a number of the more common metals.—*J. W. Cowan, A.M.I.H.V.E.*

See Heat; Hot Water; Steam.

Table II.—Latent Heat of Fusion

Substance	Latent Heat of Fusion
Aluminium	166 B.Th.U. per lb.
Copper	78 do.
Iron, cast grey	59 do.
Lead	9 do.
Nickel	122 do.
Steel	36 do.
Tin	25 do.
Zinc	43 do.

LAUNDRIES: PLUMBING & HOT WATER SUPPLY

By L. C. C. Ra‥er, A.I.E.C.

Outlining the requirements for laundry equipment in the home and also the needs of larger laundries. Notes are included for gauging the hot water supply desirable for the various machines and appliances.

Laundries in the home, following American practice, are increasing in Britain even if part of the kitchen or scullery actually houses the equipment. This tendency has been fostered by the sale of electric washing machines by electricity supply companies. The fittings required for a home laundry are the washing machine and, usually, laundry tubs.

The washing machine will require hot and cold water, but provision is not usually made for a direct connexion to the piping system. This requirement can best be met by providing taps over or adjacent to the machine. They should be not smaller than ¾ in., since the average machine has a water capacity of about 15 gal. The provision to be made for emptying the machine will depend on whether it is in a kitchen or special room. In the former case no special outlet is usually provided. In the second case a floor channel and gully may be used. In either case the machine is not directly connected to the drainage system, but the discharge from the emptying cock is allowed to fall into whatever receptacle is used.

Laundry Tubs. These are similar to deep sinks, but always have a partition in the middle, the two compartments thus formed being used for washing and rinsing, etc. The partition also serves as means of support for a wringer. The tubs are

made of vitreous enamelled iron, glazed fireclay or vitreous china, the latter being the best. They are usually supported from the floor by means of piers forming part of the fitting. One waste serves both divisions, and this should be treated as an ordinary sink waste. A weir overflow is usually incorporated in the fitting.

In a domestic house the laundry requirements are often insufficient to warrant installation of a single-purpose washtub; in such case a special two-compartment fitting may be obtained similar to that illustrated in Figs. 1–3. The left-hand compartment is adapted for use as a sink, both compartments bein employed for laundry work. Details ol the waste fitments are shown in Fig. 3. Teak inserts are often fitted to the front of the tub to prevent damage by buckets. For laundry tubs the waste should be not less than 2 in. Hot and cold water are required over each compaitment, and ¾-in. taps should be used.

Plumbing. The majority of the plumbing in a large laundry follows standard practice. Most of the special fittings, indeed, require no plumbing. The room containing the washing machines is of the most importance to the plumber. Here the great essential is floor drainage This is best provided by frequent floor channels to which the floor must slope. The washing machines also will discharge into these channels, each of which should terminate in a sealed gully. Water con-

LAUNDRIES. Fig. 1. "Fereneze" one-piece fireclay washtub and sink, with galvanized iron wringer plate; discharges into combined outlet. Overall size, 48 in. by 20 in. by 15 in. See Figs. 2 and 3. (*Shanks & Co, Ltd*)

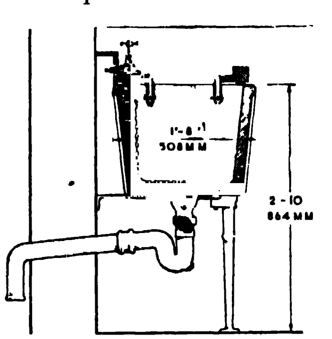


Fig 2. Cross-section of "Fereneze washtub, showing discharge pipe through back wall.

nexions both hot and cold are required for the washing machines, and they should not be reduced in size below the diameter of the openings on the machines.

Ventilation. A large amount of water vapour will be given off in the washing-room. In single-storey buildings this may be dealt with by natural ventilation if sufficient window and sky-light area is obtainable. If not, mechanical extraction ventilation with hoods over the machines will be necessary, similar to that provided in a kitchen (*see* Hotel). Drying-rooms and horses need steam and condensation connexions. The manufacturer will supply data as to steam consumption, to enable the proper pipe sizes to be determined.

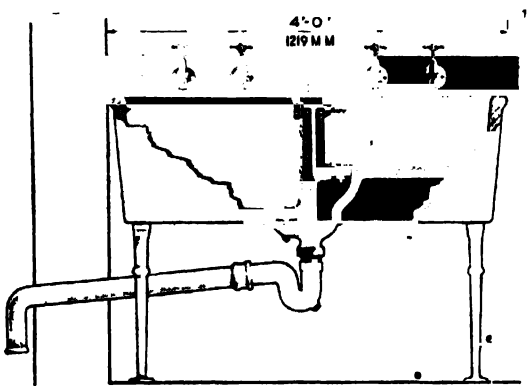


Fig. 3. Longitudinal section through "Fereneze" combined washtub and sink, showing discharge pipe through side wall: overflow; and sink bottom at higher level.

Boiler House. Most large laundries will have a boiler house with steam boilers. Cold water will be necessary here for the boiler feed tank, which usually includes its own ball valve. A floor gully will also be required. A blow-down tank should be provided to receive the water from the boilers when they are blown down. This water will probably be above boiling point, and so must not be discharged direct to the drain. A capacity equal to about one-sixth the boiler content is usually sufficient, since the boilers are never emptied when they are hot. The tank should preferably be of cast-iron and

should be fitted with a vent, which is usually about 3-in. in diameter. This is necessary to prevent pressure building up in the tank. The connexion to the drain should be taken from near the top of the tank, with a dip pipe extending nearly to the bottom, so that the coldest water flows to waste.

Hot Water Supply. The hot water requirements of laundries differ from most other buildings in that the demand is continuous. It is impossible, therefore, in commercial laundries to allow for a heating-up period and water must be heated as and when it is required. Private houses in Britain do not usually incorporate separate laundries. It is becoming increasingly common, however, to find electric washing machines installed and perhaps special sinks for washing clothes. Additions must be made to the normal domestic requirements to allow for these, as follows: for washing machines 15 gal. per hour and for laundry tubs 10 gal. per hour. These should be added to the maximum hour demand before computing the boiler and cylinder capacities. The quantities assume that the peak demand for hot water for baths will not be at the same time as that for the laundry. This assumption will apply to any normal house. It is essential that the water be really hot, 150° F. being the minimum.

When considering hot water supply for laundries in buildings such as hotels, hospitals, etc., or for public laundries, the biggest demand is created by the washing machines. These will require approximately 1,000 gal. per day and 200 gal. per maximum hour each. When being filled they may use about 20 gal. to 40 gal. per minute. The total hot water consumption will amount to about ¾ gal. to 1 gal. per piece laundered per day.

For example, if a laundry contains six washing machines the maximum hour demand for the machines only will amount to $200 \times 6 = 1{,}200$ gal. To this must be added a margin to allow for water used in other fittings—say 15 per cent.—giving a total demand of $1{,}200 \times 1 \cdot 15 = 1{,}380$ gal. per hour. If hot water is to be provided by a system including a storage cylinder or calorifier, allowance must be made for the mixing of cold water coming into the storage vessel with the hot water already in it. Precautions should be taken as described below to avoid this, but even so it will take place to an extent. To the calculated required storage capacity therefore about 20 per cent. should be added. In the present example the net storage capacity required will be $1{,}380 \times 1 \cdot 2 = 1{,}660$ gal.

When the laundry equipment is in a dwelling house the demand for them is added to the capacity required for baths, etc. As an example, a house requires a storage cylinder of 150 gal. for normal use and it contains a washing machine and two laundry tubs. The machine requires 15 gal. and each tub 10 gal., so that the total storage to be provided will be $150 + 15 + (2 \times 10) = 185$ gal. The boiler power should be increased correspondingly.

Calorifiers. Most laundries will have a steam boiler, as steam is required for the various machines. The best method, then, of providing hot water will be by means of a steam heated storage calorifier (*see* Calorifier). These heat the water quickly, most standard calorifiers being capable of heating their full water content from cold to 150° F. in about ten minutes. On no account should advantage be taken of this fact to reduce the storage capacity. In the example calculated above, where 1,660 gal. are required, a 250-gal. storage calorifier capable of heating 1,500 gal. per hour would provide 1,750 gal. of hot water per hour. This would, however, be a very uneconomical installation, since the instantaneous demand on the boiler would be very high. Extremely large steam and condense pipes and fittings would be required, and the installation would have no reserve capacity. Having calculated the load as described above, choose a storage calorifier of capacity equal to it. The heating coil should then be capable of heating this water through 100° F. in half an hour. Calorifiers are dealt with earlier in this work under their own heading.

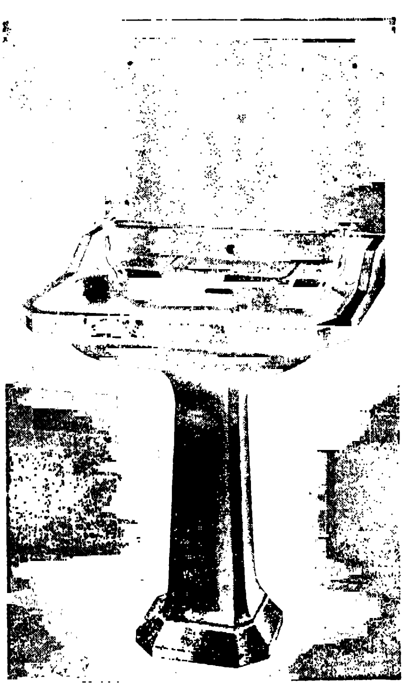
The final equipment usually found in laundries is a water softening plant, if the water is at all hard. The article dealing with water softening should be consulted for information about types and outputs. The capacity should be ample, and the figures above, if doubled, will give the approximate total quantity of water used per day. This should all be softened water.

LAVATORY BASINS: FITTING UP & FIXING

By W. J. Woolgar, M.R.San.I.

Since notes on lavatory basins are given in such articles as Bath; Flat; Hospital; and Hotel (see Plates 2, 3, 7, 8 and 12), the present contribution deals mainly with important details of fitting up and fixing. For plumbing notes see, in addition to the articles already mentioned, the one on One-Pipe System.

Lavatory basins are made in various types and sizes suitable for the position they are to occupy and the use to which they are to be put: for either domestic, office, institutional, hospital or factory use. Their construction also depends upon these circumstances, and lavatory basins are made of glazed earthenware, enamelled fireclay, vitreous china, or enamelled cast-iron. For domestic use the glazed earthenware basin is popular; and where extra strength and durability are required the enamelled fireclay basin is suitable. Vitreous china is completely non-absorbent, and though coated with a glaze, the latter is not relied on to make the ware impervious. Thus it is an ideal material for basins, on account of its non-fouling qualities and the absence of cracking and crazing. For rough usage, such as in factories, enamelled cast-iron is often used.



LAVATORY BASIN Fig 'Authentic' pedestal lavatory basin in glazed whiteware, including integral shelf; skirtings, slot overflow, ½ in. pillar valves; chromium-plated fittings

Dent & Hellyer, Ltd.

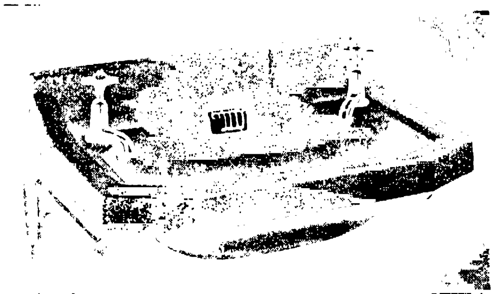
Ranges. For office, school, institutional or factory use, ranges of lavatory basins are often fitted. In these cases the basins may consist of two or more units, of the same shape as used for single basins, with overlapping joints so that the basins may be fitted and bedded together to prevent leakage between. Ranges of basins may also be obtained so constructed and supported as to form an "island site." This arrangement is suitable for schools and institutions and factories, where a number of persons require to wash at the same time.

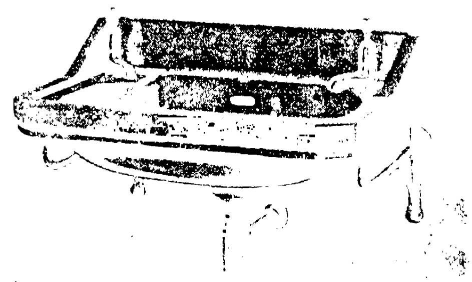
The shape of the modern lavatory basin has been to a certain extent standardized, inasmuch as the front is flat while the back is circular or oval in shape. A basin that has a straight edge is suitable and convenient to the user, as it affords accessibility for its purpose.

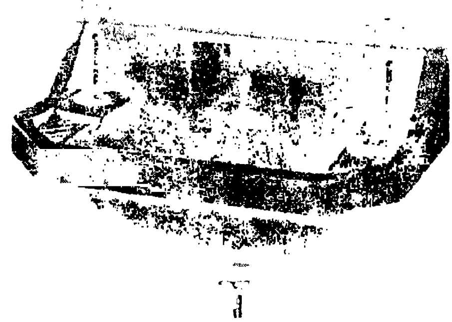
The Overflow. Probably the most important point to consider in the selection of a lavatory basin apart from its general utility is the overflow. This should be accessible from the point of view of cleansing. Greasy, soapy matter off the top of the water is liable to escape down the overflow and, if the overflow cannot be easily cleansed, will cling to the sides and accumulate. This accumulation, besides being liable in time to block the pipe, will emit an unpleasant odour. For this reason the overflow should be open to view, accessible for cleansing and, what is equally important, should be large enough to receive and carry away the discharges from both hot and cold water taps when running together at their maximum discharge. These points suggest that an open overflow as depicted in some of the illustrations is more suitable than the type which terminates at the basin in a series of small holes. The overflow of the modern basin is cast integral with the basin itself, and the overflowing water discharges into the waste above the trap.

Back or side skirtings to lavatory basins prevent splashing on to the wall or surround. It is usual to fix a splash-back, especially with domestic basins.

Valves. Except in the case of hospital basins the hot and cold valves should be







LAVATORY BASIN. Figs. 2 and 3. Basins carried on towel-rail brackets fixed to wall : (above) " Isla," porcelain enamelled c.-i. (*Carron Co.*) ; (top right) " Roxul " vitreous china, standing waste (*Shanks & Co., Ltd.*). Fig. 4 (bottom right), " Standard, Kent," vitreous china basin fixed to wall by concealed wall hangers (*Ideal Boilers and Radiators Ltd.*)

separate, and the nozzle of the valves should be in such a position that they are not submerged when the basin is filled to overflowing. (*See* Taps.)

The fixing for lavatory basins depends upon the type in question ; the pedestal basin relies upon the pedestal, which in most cases is fixed to the floor. Basins fixed against the wall may be supported on cast-iron cantilever brackets built into the wall, or on cast-iron brackets, plain painted or enamelled, screwed to fixings or plugs built into the wall. A combination stand and bracket is sometimes used, as are also wooden surrounds constructed to form a cupboard under and at the same time provide a support for the basin.

Fixing. The height at which a lavatory basin should be fixed is governed by circumstances such as its position and the type of person to use the basin. It will generally be found, however, that a height of 2 ft. 7 in. to 2 ft. 10 in. from the floor to the top of the front edge of the basin is suitable for the average person.

Various methods are used to support basins (*see* Figs. 6-8). It may be secured to the wall by means of screws passed through the back skirting, or be carried on cast-iron towel rail brackets screwed to fixings in the wall. For ranges of basins, cast-iron cantilever brackets are used, cut and pinned to the wall. Other types of bracket may be provided that act as a stand from the floor ; or the support may take the form of a wooden cupboard, which will in addition act as a space for utensils and conceal the plumbing work.

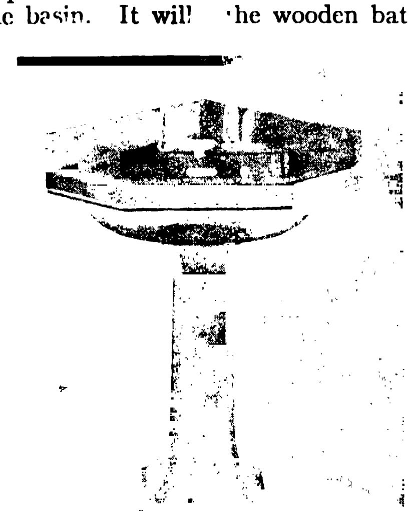
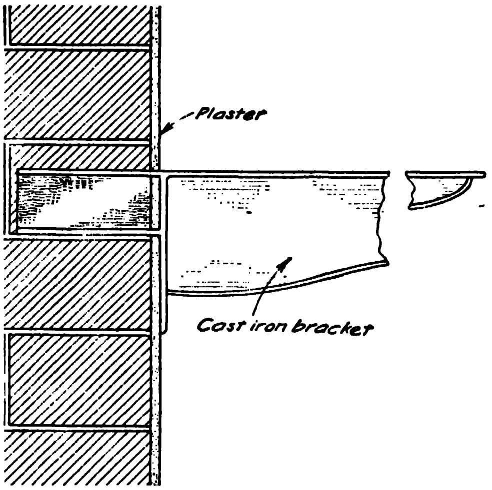


Fig. 5. " Aptus " pedestal corner lavatory basin in white earthenware, with chromium-plated fittings (*Shanks & Co., Ltd.*).

For fixing cast-iron towel rail brackets a batten or block should be built into the wall exactly behind the position of the back plate, so that the bracket may be screwed to this fixing. In building-in the wooden batten or block, care should be taken to cut a dovetailed hole and block so that when the block is bedded in with cement, strength is afforded against pulling out.

Where fixed against a tiled wall the above procedure may be adopted, wooden grounds being built-in behind the tiled face ; in such case, holes will be drilled through the tiles for the screws. Another method is to drill the tiles and brick in the exact position of the screw-holes in the bracket and insert wall plugs into which the screws may be driven.



LAVATORY BASIN. Fig. 6. Supports : Cast-iron cantilever bracket fixed to wooden ground.

It sometimes happens that a basin has to be fixed against a lath-and-plaster partition. It is not always possible in these cases to screw the brackets to the studs, owing to their unsuitable position, so a batten or board of suitable length should be let into the plaster work and fixed to the studs, so that the bracket may be screwed to the board when the wall has been made good.

Brackets should be levelled up when being fixed, and the basin tried on. It sometimes happens that the casting is not true, in which case the bracket will have to be adjusted to suit. A slot is provided in the basin to fit on to a protruding nib on the bracket.

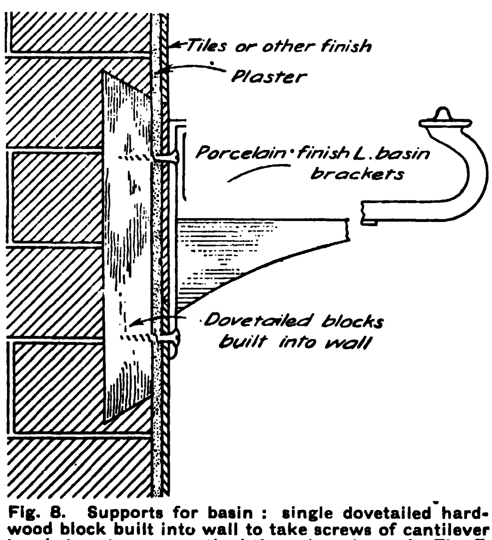


Fig. 8. Supports for basin : single dovetailed hard-wood block built into wall to take screws of cantilever bracket ; stronger method than that shown in Fig. 7.

Fitting Up. The metal waste fitting is bedded into the waste hole in the basin, using a suitable material such as red and white lead and chopped hemp ; a lead washer is inserted between the basin and back-nut. Rubber rings are sometimes supplied for this purpose, to obviate the use of red and white lead. If the jointing material is used it must be kept away from the thread. Care should be taken in tightening up the back-nut, so as not to put too much pressure on the basin.

The taps may be bedded into the tap-holes with red and white lead or with plaster of paris in this case ; also a lead washer is interposed between the basin and the back-nut. A disadvantage of using plaster of paris is that difficulty may arise in removing the tap, should it be necessary to do this on a later occasion. Rubber tap sets are now supplied to obviate the use of these jointing materials, and to facilitate the easy fixing and removal of taps. The set consists of a rubber block to fit over the base of the tap as it fits into the hole in the basin, and a rubber washer to insert between the basin and the back-nut.

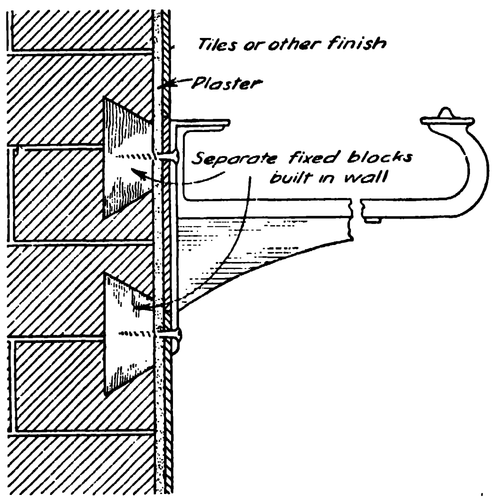


Fig. 7. Supports for basin : separate dovetailed blocks built into wall to take screws at top and bottom of bracket wall-piece. A more secure method is shown in Fig. 8.

Very often it is found that the tap washer has deteriorated, owing to the methods used in the manufacture and plating of the tap, and that the body of the tap is difficult to remove. It is advisable to see that a suitable washer is provided to the tap before it is fixed into the basin. This will also allow

the body of the tap to be in a manipulative state. Very often a basin is broken in attempting to re-washer a tap in position, owing to the body of the tap not being easy to remove. In this case it is advisable to remove the tap from the basin before attempting to unscrew the top.

Metal waste plugs are likely to chip or damage the basin. A plug of rubber or other suitable material should be used instead. The plug is secured by means of a chain attached to a chain stay, which is fixed through and bolted to the basin in a suitable position above the overflow level. The chain stay should be bedded through its hole in the same manner as described for the valves and waste.

Lift-up or "pop-up" wastes may be fitted. This type consists of a fixed metal plug which fits into a seating in the brass waste; it is raised or lowered by operating a lift-up handle fitted through the top of the basin.

LEAD: PROPERTIES AND APPLICATIONS IN PLUMBING WORK

By W. F. Chubb, Ph.D., B.Sc., F.R.I.C., F.I.M.

The properties and most important characteristics of metallic lead. Tabular information is given and notes are included on Lead Pipes (fuller details will be found under the heading Pipe and Pipe Fittings : I, Lead). *See also* Cast Leadwork ; Cast Sheet Lead ; Extruded Sections ; Lead-Burning ; Leadwork, Creeping ; Leadwork, Ornamental ; Pipe Bending ; Pipework ; Roofwork in Lead.

Historically, lead is one of the oldest metals known to man; probably the earliest specimen is a figure from 3000 B.C. found in the Temple of Osiris at Abydos, now preserved in the British Museum. In 2000 B.C. it was used by the Chinese for coinage, but undoubtedly the most interesting application of lead in ancient times was its use by the Romans for water pipes, these being made by them in 15 standard sizes and regular 10-ft. lengths. Examples are to be seen at the Roman baths at Bath, these pipes having been formed from cast lead sheets with fused seams. Also in the British Museum.

Until relatively recently Great Britain derived all its lead from Derbyshire, but with the development of other sources supplies now come from the United States, Australia, Canada, Mexico, Silesia, Burma, Spain, North Africa, Peru, and Argentina, in that order of importance. According to statistics for 1944 the U.S.A. produced close on 50 per cent. of estimated world tonnage, the output being approximately 1,100,000 short tons. In 1948 it was stated that the world's known resources were limited to about 18 years.

Minerals and Extraction. More than 60 minerals containing lead are known, the lead of commerce being obtained mainly from one source, the mineral galena, the sulphide of lead, PbS. With the development of flotation concentration processes, however, less pure ores may now be profitably worked, and this advance has rendered production much simpler.

The extraction process consists in roasting the lead concentrate containing about 60 per cent. of lead, and then reducing the formed oxide to impure lead bullion in the blast furnace, the reducing agent being coke. The metal is then refined to extract any silver present, the product being a lead of not less than 99.99 per cent. purity. Table 1 gives typical analyses for the various grades.

TABLE 1—**Analyses of Commercial Lead**

Impurity	Corroding lead	Chemical lead	Common Desilvered lead	Soft Undesilvered lead
Silver max. %	0·0015	0·020	0·002	0·002
„ min. %	—	0·002	—	—
Copper, max. %	0·0015	0·080	0·0025	0·04
„ min. %	—	0·040	—	—
Silver & copper together, max. %	0·0025	—	—	—
Arsenic, max. %	0·0015	—	—	—
Antimony & tin together, max. %	0·0095	—	—	—
Arsenic, antimony & tin together, max. %	—	0·002	0·015	0·015
Zinc, max. %	0·0015	0·001	0·002	0·002
Iron, max. %	0·002	0·002	0·002	0·002
Bismuth, max. %	0·05	0·005	0·15	0·005
Lead (by difference), min. % ..	99·94	99·90	99·85	99·93

Secondary Lead. The production of lead from scrap is now an important industry, the principal source being old storage accumulators, lead sheathings, sheets, pipes, and other lead products. This reclamation accounts for almost 50 per cent. of the total lead tonnage produced. In consumption (1944 production statistics) about 40 per cent. is used for accumulators and cable sheathing, 13 per cent. as red and white lead and litharge, 6·4 per cent. in building, 3·8 per cent. for for solders and the remainder for automobiles, bearing and type metals, caulking, ammunition and miscellaneous.

A. PROPERTIES OF THE METAL

Lead is bluish-grey in colour, and when freshly cut or melted has a bright metallic lustre which, however, tarnishes rapidly due to oxidation. This oxidized film forms a protective layer on the surface. The density of the metal is high, being 11·340 gms./c.cm. or 0·4097 lb./c.in. It is easily worked and ready cut, these facts forming the basis of its wide and varied use. The tensile strength is low, an average of ten rolled sheets giving 2,594 lb./sq.in. or 1·16 tons per sq.in., and the elongation at fracture is about 46 per cent. in a 2 in. gauge length. When pure, lead is highly resistant to corrosive attack, and for this reason is much used in the construction of chemical plant.

For purposes of design, the basis of calculation is the creep strength and not the tensile strength, the reason being that lead deforms very readily under stress without fracture. In practice, the maximum allowable stress is about 350 lb./sq. in. at normal temperatures, but this depends on factors over which the plumbing and building operator has no control.

As to thermal properties, Table II correlates the most important considerations for the plumbing and building trades in the case of common de-silvered lead.

Another important property of lead is that when distorted or worked by cutting or machining the metal hardens but immediately begins to soften again. This results from the fact that the recrystallization temperature is below 0° C., so that self-annealing occurs if the metal is allowed to stand at normal temperatures.

Casting Shrinkage. The amount of casting shrinkage to be allowed for in practice depends to some extent on the manner in which the casting of the metal is carried out. Thus, if a portion of the casting solidifies first, part of the shrinkage will be made up again by the molten metal still being supplied. The shrinkage allowance will then be less than if the whole mass solidified together. For this reason, the shrinkage allowance is a minimum of $\frac{1}{4}$ in. per 10 ft. in the case of sheets cast in sand, but in the case of more solid castings this allowance must be increased to approximately $\frac{5}{16}$ in. per ft. The most appropriate allowance must accordingly be determined only in practice.

Available Forms. Lead is sold from the refineries in the form of pigs or bars, these weighing usually from 80 to 120 lb. They are then used as raw material by lead manufacturers for producing lead pipe, lead sheet, and other commercial forms. Lead pipe is available in extruded form at any desired wall thickness in diameters up to 12 in., and for larger pipes the metal is formed over a mandrel. Lead sheet is produced in a wide range of thicknesses and widths, the thickness of sheet in most general use ranging from $\frac{1}{64}$ in. (1 lb. per sq. ft.) to $\frac{1}{2}$ in. (30 lb. per sq. ft.).

A standard roll of sheet is 8 ft. wide and 20 ft. long, but is usually ordered to definite sizes in order to save cutting on site. In America, widths are available up to 12 ft. and lengths are limited to about 75 ft., depending upon the thickness. For caulking or similar purposes, lead is supplied in cake of varying weight.

B. SHEET LEAD

Rolled or Milled Sheet. The greater part of the lead sheet in use today is produced by rolling or milling, and is thus called *milled lead sheet.* The process involves the melting of pig lead and casting into slabs about 5 in. thick. These slabs

TABLE II.—Thermal Properties

Melting Point	327·4°C.
Boiling Point	1,725°C.
Coefficient of Linear Expansion, 17°–100°C.	0·0000293°C.
Mean Specific Heat, liquid state ..	0·034
Heat to raise metal from 15°C. to its Melting Point, B.Th.U's per lb. ..	18·0
Increase in Volume from 20°C. to Liquid at Melting Point	6·1 per cent.
Thermal Conductivity, at 0°C.	0·083
at 100°C. ..	0·081
at Melting Point	0·038

LEAD. Fig. 1. Cast sheet lead in process of manufacture, the molten lead being run down a bed of prepared sand on the casting bench to the thickness allowed by the "strike." (See also p. 217).
Photo: Lead Industries Development Council

are passed through the rolling mill and reduced to approximately 1 in. thick. Cut into suitable sizes each piece is rolled down to the final size required. Lead sheet is sold and known by its weight per sq. ft., thus: 3 lb. lead, 4 lb. lead, etc.; roughly every 1 lb. of weight corresponds to $\frac{1}{64}$ of an inch of thickness.

The weights of milled sheets as used in building are given in Table III. Heavier

TABLE III—Milled Sheet Lead for Building Work

Weight in lb. per sq. ft.	Thickness in inches	Nearest Imperial Standard Wire Gauge	Thickness in mm.
2½	0·042	19	1·07
3	0·051	18	1·3
3½	0·059	17	1·5
4	0·068	16	1·73
4½	0·076	15	1·93
5	0·085	14	2·16
6	0·101	12	2·57
7	0·118	11	3·00
8	0·135	10	3·43
10	0·169	7	4·29

sheets as used in the chemical and engineering industries are defined in Table IV, based on thickness.

In rolling lead sheet the tolerances vary considerably, and sheets of 5 lb. or over may be rolled with considerable accuracy, but the usual rolling tolerance is about + or − 5 per cent. Considerable wastage may occur in the final trimming to size, and about 3 in. must be allowed for this operation.

Sheet Lead in Building Work. Milled lead sheet is utilized in many ways in building construction, the principal uses being waterproofing of roofs. (*See* Roofwork in Lead, *also* Cast Sheet Lead.) Its unusual durability in exposed positions under severe weathering conditions, together with the ease with which it may be worked and bossed to any desired shape, make lead an ideal material for all types of guttering, flashings, hip and ridge coverings, dormer roof coverings, soakers and various weatherings. Of recent years, however, aluminium alloys have become a serious competitor to lead in many of these applications. (*See* Aluminium; Flashings; Gutters; Roofwork.)

Milled lead sheet is also frequently used for covering flat roofs, the lead being laid in sections of suitable size and made watertight at the joints by means of rolls and drips. Within the building, sheet lead is often used for making safes or trays beneath baths, slop-sinks, water

TABLE IV.—Milled Sheet Lead Used in Chemical and Engineering Work

Thickness in inches	Weight lb. per sq. ft.	Thickness in mm.
1/64	0·93	0·40
1/32	1·85	0·79
1/16	3·71	1·58
3/32	5·56	2·38
1/8	7·42	3·175
3/16	11·13	4·76
1/4	14·83	6·35
5/16	18·54	7·93
3/8	22·25	9·52
7/16	25·95	11·11
1/2	29·67	12·7
9/16	33·38	14·28
5/8	37·08	15·875
11/16	40·79	17·47
3/4	44·50	19·05

closets and cisterns, and for lining sinks and water storage tanks. Built-up lead-lined storage cisterns are being used to a greater extent than for many years. Since the weight of water is not taken by the lead lining extra heavy metal is not essential, and 6 lb. milled lead sheet is suitable for all sizes of cistern. The joints may be either lead-burned or wiped.

C. CAST LEAD

Cast Sheet Lead. For decorative and certain chemical purposes cast sheet lead is preferred. (*See* Cast Sheet Lead; Dormer.) It is held to be more resistant to corrosion and creep than a similar grade of metal in the milled form, but this

has not been fully investigated as yet from a scientific aspect. Cast sheet is not now used to any great extent, but certain firms specialize in its production, and it is always made in small quantities by lead workers from waste materials. Old cast sheet lead from church roofs, damaged by mechanical agencies, is often stripped, melted down, and replaced.

The size of the sheet is determined by that of the bed, commonly 12 ft. by from 3 ft. to 5 ft. The thickness is determined by the setting of the " strike " with which the metal is spread, and may be from ⅛ in. bare up to any manageable thickness. A description of the process, with diagrams, is given under the heading Cast Sheet Lead.

Ornamental Cast Lead. The metal lends itself readily to casting in shaped moulds, and for centuries cast lead has been used for rainwater heads, shaped or moulded fittings, urns, statuary and decorative architectural work. (*See* Cast Leadwork; Leadwork, Ornamental.) Most ornamental leadwork for architectural purposes is cast flat on a bed of sand on a casting bench, the nature of the metal permitting the casting to be bent or worked to a shaped form at a later stage.

A mould of the surface decoration required on the lead is formed in the sand bed and the shape of the flat sheet required is set out geometrically by the craftsmen. (*See* diagrams in page 215.) There is no other metal which can be handled in the cast form quite in this way.

D. LAMINATED LEAD

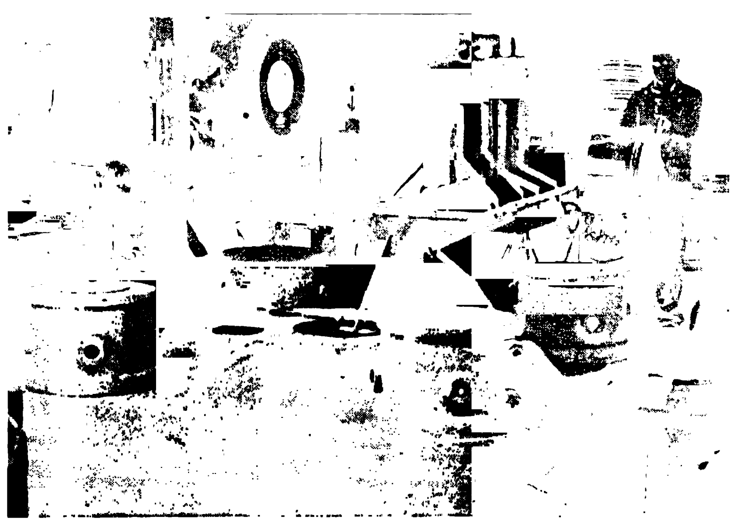
Laminated lead is thin sheet or foil, used largely for protective and for waterproofing purposes, most commonly in 4 oz. and 5 oz. substance. It is marketed in rolls or in sheets. The usual weights in which it is produced are: 1½, 2, 4, 5, 8, 10, 12, and 14 oz. per sq. ft. The sizes of laminated lead sheets are: 22 in, by 18 in. for all weights, and up to 6 ft. by 2 ft. for weights above 4 oz. per sq. ft. It is also possible to obtain:

1 to 1½ oz. in sizes up to 22 in. by 22 in.
2 to 2½ oz. in sizes up to 72 in. by 22 in.
3 oz. in sizes up to 90 in. by 22 in.

3½ oz. and upwards regularly supplied in 84 in. by 22 in. and, exceptionally, 90 in. by 24 in.

E. LEAD PIPE

Originally, lead pipe was produced by bending the sheet over a mandrel and joining the seam by either welding or soldering. This procedure is now only used in producing pipes over 12 in. in diameter, and in all other sizes the extrusion process is employed. (*See* Extruded Sections, pages 374 to 376.) Such pipes are manufactured in a large number of sizes, external and internal diameters being varied according to the size and weight of pipe required for a variety of purposes. Pipe is therefore specified by internal diameter and weight per lineal yard. (*See further under* Pipes, Lead.) The method of manufacture is such that any exact diameter or weight of pipe may be produced to order.



LEAD. Fig. 2. Lead pipe of small diameter, produced by extrusion in a hydraulic press; on emerging from press it passes through a water cooler and is wound on drums to form coils; large diameter pipes are kept straight lengths.
Photo. Lead Industries Development Council

Soil and Waste Pipes. Lead is generally favoured for internal domestic soil and waste pipes owing to its many advantages, not the least of which is its ease of bending. There are nevertheless several considerations which affect the efficient life of such pipes, these being:

(*a*) the corrosive character of the surrounding soils;

(*b*) the corrosive action of the conveyed water ;

(*c*) stresses imposed by the water pressure, which may have an accumulative effect over long periods ;

(*d*) additional stresses imposed by the manner and conditions of laying the pipe.

Many of the factors affecting the corrosion of lead by soils are not yet fully understood, but it is nevertheless clear that both alkaline and acidic soils promote corrosion of the metal, and even more rapid corrosion is likely if the soil contains soluble salts which increase its electrical conductivity. Such experiences are not, however, very common, but where conditions conducive to corrosion are suspected the pipe should be wrapped with felt impregnated with bitumen.

Water Service. As to the action of domestic water, normal supplies do not affect lead pipes to any appreciable extent, but if difficulties of this kind are encountered the most appropriate remedy is a suitable pre-treatment of the water at the waterworks prior to its entry into the lead service pipes. In other instances, a more convenient method may be the use of alloyed lead, such as B.N.F. Ternary Alloy No. 2 (*see below*).

Rectangular Pipe. This is manufactured in a number of sizes from 2 in. by 2 in. to 6 in. by 4 in., the commonest being $3\frac{1}{2}$ in. by $3\frac{1}{2}$ in.; 4 in. by 3 in.; 5 in. by 4 in.; 6 in. by 4 in.—in 12 and 15 ft. lengths and weighing 8 lb. per square foot of lead. Rectangular pipe may be made from sheet lead by shaping over a suitable former and burning the seam.

Lead-Burning in Building Work. Lead-burning has for many years been used in seaming cast lead rainwater pipes, and decorative work for special purposes. Improvements in technique and portable equipment now permit the process to be used over a much wider field. As a result, the current tendency in leadworking is to reduce the amount of shaping by laborious bossing from the flat sheet, and to replace this by cutting to pattern, bending up and burning the joints. Lead-burning is particularly useful for repair and maintenance work, since *in situ* burning permits sections of gutters, flashings or roofings to be cut out and replaced with new material without taking down the whole of the leadwork.

Lead-burning is especially suitable for soil and waste pipes, the joints being strong and less bulky than wiped joints (*see* Lead-Burning).

F. ALLOYS OF LEAD

Table V gives details of the most important lead alloys used in the plumbing, sanitary engineering, and allied trades.

Silver-Copper. Alloying always increases the strength and hardness of lead. For example, in the silver-copper-lead alloy mentioned in the Table the tensile strength and resistance to creep are greater, it has an outstanding resistance to prolonged internal pressures, and will withstand higher stresses than does ordinary lead of similar dimensions. These facts then

TABLE V.—Alloys of Lead

Trade Name or Use	Lead %	Calcium %	Antimony %	Tin %	Silver %	Cadmium %	Copper %	Tellurium %
Chemical Lead ..	99·90 min.	—	—	—	—	—	—	—
Common Desilvered Lead	99·75 min.	—	—	—	—	—	—	—
Sheathing Lead ..	Rest	0·02–0·1	—	—	—	—	—	—
Hard Lead	Rest	—	4–6	—	—	—	—	—
Antimonial Lead ..	Rest	—	8–12	—	—	—	—	—
Grid Metal	Rest	—	9		—	—	—	—
Silver Lead Solder ..	97·5	—	—	1	1·5	—	—	—
Soft Solder	80	—	—	20	—	—	—	—
Solder, half & half ..	50	—	—	50	—	—	—	—
Plumber's solder ..	66	—	—	34	—	—	—	—
Babbitt	75–85	—	10–15	5–10	—	—	—	—
B.N.F. Ternary Alloy No. 2	Rest	—	—	1·5	—	0·25	—	—
Silver/Copper Lead ..	Rest	—	—	—	0·005 max.	—	0·005 max.	—
Tellurium Lead ..	Rest	—	—	—	—	—	—	0·05–1

allow a measureable and profitable reduction in weight to be effected, and this reduction in the wall thickness is very economical as regards cost and weight per yard.

Tellurium. Though introduced in 1933, tellurium-lead has not yet become popular in the plumbing and sanitary engineering trades, despite all its known and proved advantages. When subjected to stress, this alloy is appreciably strengthened, whereas other lead alloys would be weakened in certain respects. It also has much superior tensile strength and resistance to fatigue as compared with ordinary lead, so that a great saving in weight results from its use.

Ternary. B.N.F. Ternary Alloy No. 2 (Brit. Std. 1941) is a recent addition to the range of lead alloys of advantage in the plumbing and allied industries. (The term Ternary denotes its composition of three substances.) This alloy is to be recommended for sheet and pipe as it is much stronger and tougher than lead. This improved strength again allows lighter sections to be employed, and the British Waterworks Association officially permits a reduction of 30 per cent. from the weight of ordinary lead pipes in cases where this alloy is used for work above ground level.

Regulus. Antimonial lead, or Regulus Lead, usually contains up to about 8 per cent. of antimony as a hardening agent, but other varieties of antimonial lead may contain as much as 12 per cent. of antimony. These alloys have been much used in America for roofing purposes, the reason being that antimony additions provide an outstanding benefit in rendering lead resistant to atmospheric corrosion. Antimonial lead is also the standard alloy for battery plates and terminals.

British Standards. The following British Standards have been drawn up in connexion with lead, lead alloys and allied products.

Lead pipes (not for chemical purposes)	602/1939
Lead pipes (B.N.F. Ternary Alloy No. 2)	603/1941
Lead pipes (Silver/copper lead)	1085/1946
Milled lead sheet and strip for building purposes	1178/1944
Lead traps (drawn)	504/1944
Lead for chemical purposes, Types A and B	334/1934
Regulus metal	335/1928
Solder, soft	219/1932
Solder, cored, resin filled	441/1932

NOTE.—Certain standard methods of analysis are included in B.S. No. 334/1934.)

LEAD-BURNING OR WELDING: PRINCIPLES, METHODS AND EQUIPMENT

By W. L. Kilburn, R.P., M.Inst.W.

Here one of the most important adaptations of welding to sanitary work is described in detail and in a most practical manner. It is arranged in five main sections: A, systems of lead-burning ; B, most common system, the oxy-acetylene blowpipe ; C, methods of making joints ; D, external work ; E, internal work. Two folding plates facing pages 656 and 664 illustrate methods in lead-burning. See *also* Joints : (1) Lead, Wiped ; Lead ; Pipe : (1) Lead ; *and* Welding.

Lead-burning may be defined as a process for joining lead by welding without the use of other metals.

The edges of the materials to be joined are melted together by means of a small concentrated gas welding flame. Extra lead of the same composition as that of the parent metal is added when necessary, as when lead-burning a flat seam.

Developments in lead-burning technique, the introduction of lead alloys and particularly improved high pressure equipment, have widened the scope for lead-burning in modern building construction.

Lead-burning is used extensively in the construction of exterior plumbing work such as chimney breasts, gutter backs, box gutters, lead slates, cesspools, down spouts, lead heads, etc., and for interior work in connexion with sanitary installations, waste, soil, and anti-siphon pipes, etc. Brasswork such as thimbles, ferrules, inspection eyes and boxes, are lead-burned on many such installations.

Temperature. The temperatures required for lead-burning must be greater than the melting point of lead (621° F.). While this flame temperature is greater than that required for soldering, the actual amount of heat used is not great, for the quantity of lead melted at any one time is so small, and the process so quick, that

little heat is lost by conduction. The temperature is not so great as to cause charring of woodwork. In a properly prepared joint there is no opportunity for this to occur.

Flame temperature of the most used gases for lead-burning is as follows :

	With Air	With Oxygen
Acetylene ..	2,550° C.	3,500° C.
Hydrogen ..	1,700° C.	2,300° C.
Coal gas ..	1,600° C.	2,000° C.

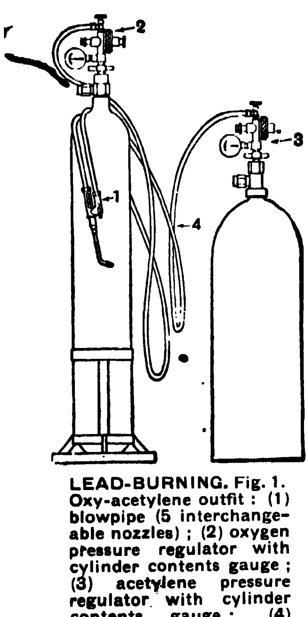
There are several processes available for lead-burning, each of which is named from the mixture of gases used in it, and are as follows :

Oxy-Acetylene	Oxygen and Acetylene.
Oxy-Hydrogen	Oxygen and Hydrogen.
Oxy-Coal Gas	Oxygen and Coal Gas.
Aero-Hydrogen	Air and (Hydrogen Generated).
Air-Acetylene	Air and Acetylene.
Air-Hydrogen	Air and Hydrogen.
Electrical System	Carbon Arc.

A. THE SEVEN SYSTEMS

The Oxy-Acetylene System. With this system, both oxygen and acetylene are obtained compressed in steel cylinders, the oxygen being subjected to a pressure of approximately 1,800 lb. per sq. in., and the acetylene at a pressure of 225 lb. per sq. in.

The outfit consists of two cylinders containing the compressed gases, each with suitable pressure regulators. The gases are led by flexible rubber tubing to the blowpipe in which they are mixed.



LEAD-BURNING. Fig. 1. Oxy-acetylene outfit : (1) blowpipe (5 interchangeable nozzles) ; (2) oxygen pressure regulator with cylinder contents gauge ; (3) acetylene pressure regulator with cylinder contents gauge ; (4) 3/16 in. bore rubber tubing and connexions.

The amount of gas required for any particular work or thickness of lead to be burned is controlled by calibration adjustment valves on the regulators. There are a number of graded nozzles which give the operator a wide choice of flame size, according to the work in hand. Cylinders are obtainable in various sizes, the smallest outfit being a portable model weighing less than 30 lb.

The oxy-acetylene or D.A. system of lead-burning is the latest and best method to be adopted by the domestic plumber.

The temperature of the oxy-acetylene flame is far higher than any other combination of gases, and with the highly concentrated flame obtainable at the blowpipe nozzle, very intricate work presents no difficulty. The high temperature is an advantage, particularly where a spreading outer envelope of flame at the blowpipe nozzle is not desired. Therefore, distortion of the lead does not occur to the same extent as is the case with other lead-burning systems.

The Oxy-Hydrogen System. This system involves the use of compressed oxygen and hydrogen in steel cylinders. The gas is compressed in the cylinders to 120 atmospheres, approximately 1,800 lb. per sq. in.

The outfit consists of two cylinders containing the compressed gases—hydrogen and oxygen — pressure regulators, rubber tubing, and blowpipe with the requisite number of nozzles.

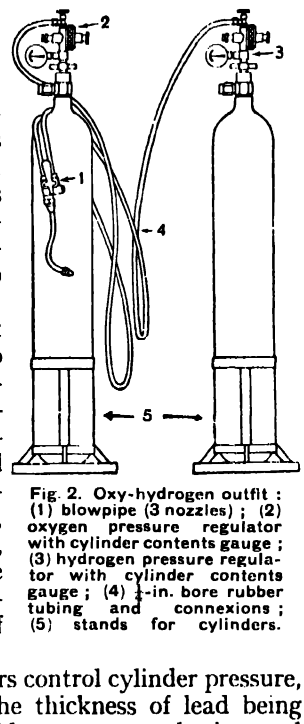


Fig. 2. Oxy-hydrogen outfit : (1) blowpipe (3 nozzles) ; (2) oxygen pressure regulator with cylinder contents gauge ; (3) hydrogen pressure regulator with cylinder contents gauge ; (4) ¼-in. bore rubber tubing and connexions ; (5) stands for cylinders.

The regulators control cylinder pressure, according to the thickness of lead being burned. Shoulder taps may be inserted in the rubber tubing between regulators and blowpipe, and may be used for adjusting the flame at the blowpipe nozzle.

Calibration pressures for lead-burning are approximately 5 lb. per sq. in.

The Oxy-Coal Gas System. Coal gas is obtained either in compressed steel cylinders at 120 atmospheres, or 1,800 lb. per sq. in., or by town gas mains at a pressure usually equal to 6-in. water column.

The complete plant is illustrated by Fig. 3. This shows coal gas being supplied from the town's main, and includes the following equipment: Cylinder of compressed oxygen, pressure regulator, shoulder taps, injector blowpipe, back pressure valve connected to gas main. Where this method is used, it is necessary to use the injector type of blowpipe. The reason for this is that the pressure in the gas main is not sufficient to give large volumes through the small orifices in the blowpipe without assistance from the oxygen. This blowpipe is constructed to enable the oxygen, which is under pressure, to suck larger volumes of coal gas through it than would be the case were no injector fitted.

Aero-Hydrogen System. In this system hydrogen under low pressure is used. The gas is usually generated in a special machine. The air compressor used in conjunction with the generator is in the form of hand or water bellows. Rubber tubing is connected from the blowpipe to the breeches piece, which includes the taps regulating the flame at the blowpipe nozzle. From this point a further rubber tube is connected to the gas supply at the generator, and another tube is connected to the air compressor.

The low pressure system has been used mostly in chemical works, and is not adaptable in domestic plumbing. It is becoming obsolete.

Air-Acetylene System. With this system, acetylene is obtained compressed in steel cylinders, and air is taken from the atmosphere. The blowpipe (*see page* 127) is fed by the acetylene gas under pressure, a quantity of atmospheric air being drawn into the mixing chamber providing a bunsen type of flame at the end of the nozzle.

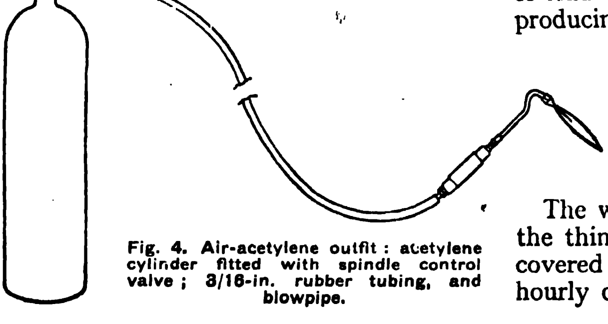
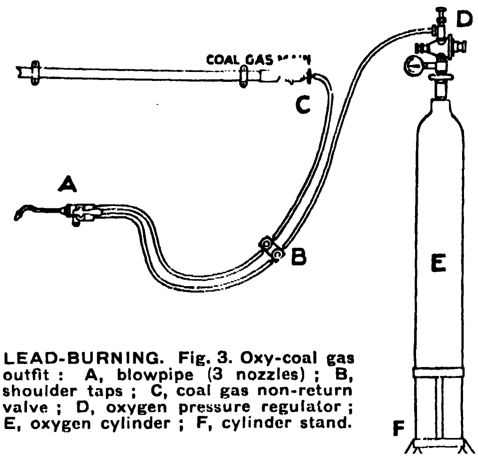


Fig. 4. Air-acetylene outfit: acetylene cylinder fitted with spindle control valve; 3/16-in. rubber tubing, and blowpipe.

This flame is ideal for burning on the flat up to 8 lb. lead per ft. super, but it is not recommended for other types of burning.

Air-Hydrogen System. Similar in all respects to air-acetylene, gas supplied



LEAD-BURNING. Fig. 3. Oxy-coal gas outfit: A, blowpipe (3 nozzles); B, shoulder taps; C, coal gas non-return valve; D, oxygen pressure regulator; E, oxygen cylinder; F, cylinder stand.

in steel cylinders under pressure. Air supplied from atmosphere. Used for burning on the flat only up to 8 lb. lead per ft. super.

Electric Arc System. This system utilizes electric current from the battery to form the heating medium.

Two wires are connected to the battery, one to the positive, and the other to the negative terminal. At the opposite end of the wires is the holder, to which is fitted a carbon pencil as a resistance, and by passing a current with low voltage but high amperage, the carbon pencil becomes red-hot. This pencil when red-hot, is used for fusing the lead together.

This system of lead-burning is confined to battery maintenance.

B. OXY-ACETYLENE BLOWPIPE

The oxy-acetylene lead-burning blowpipe has been designed so that its capacity can be varied according to the thickness of lead to be burned, the smallest nozzle producing a flame of the smallest known dimensions. The nozzle orifice through which the two gases pass is less than 1/100th of an inch in diameter. This enables lead of the thinnest sheet to be lead-burned.

The whole range of lead-burning, from the thinnest to the thickest lead, can be covered with five sizes of nozzles, the hourly consumption ranging between five

TABLE I. SIZES OF NOZZLES FOR VARIOUS STRENGTHS OF LEAD

Weight of Lead	Flat	Upright	Overhead	Under-hand	Horizon-tal
2 & 3 lb.	No. 2	No. 1	No. 1	No. 1	No. 1
4 lb.	No. 3	No. 2	No. 2	No. 2	No. 2
5 lb.	No. 3	No. 2	No. 2	No. 2	No. 2
6 lb.	No. 4	No. 3	No. 2	No. 2	No. 2
8 lb.	No. 4	No. 3	No. 3	No. 2	No. 3
10 lb.	No. 4	No. 4	No. 3	No. 3	No. 3
20 lb.	No. 5	No. 5	—	—	No. 5
25 lb.	No. 5	No. 5	—	—	No. 5
30 lb.	No. 5	No. 5	—	—	No. 5

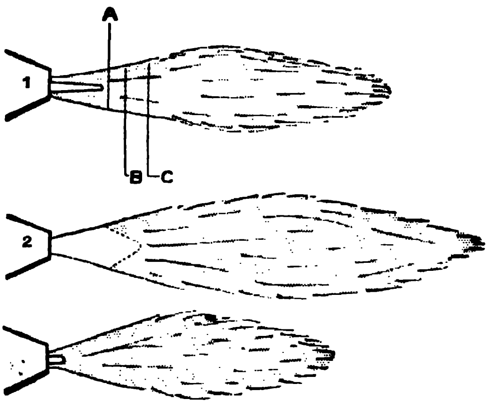
TABLE II. APPROXIMATE CONSUMPTION OF GASES AND WORKING PRESSURES REQUIRED FOR VARIOUS NOZZLES

Size of Nozzle	Working Pressure for both Gases	Oxygen Consumption Pr. Hr.		Acetylene Consumption	
		litres	cu. ft.	litres	cu. ft.
No. 1	1½ lb. sq. in.	5	·175	5	·175
No. 2	2½ lb. „ „	12	·125	12	·425
No. 3	3 lb. „ „	31	1·1	31	1·1
No. 4	4 lb. „ „	62	2·2	62	2·2
No. 5	5 lb. „ „	125	4·4	125	4·4

Note.—1 cu. ft. = 28·32 litres.

litres and 25 litres of each gas. This blowpipe provides a stable flame of maximum temperature combined with minimum velocity. This combination makes the operating rate so rapid that there is practically no loss of heat conductivity.

Oxy-Acetylene Flame Adjustment. The proper setting of the flame is most important in lead-burning, and incorrect setting will spoil any joint. An excess of oxygen will reduce portions of the molten metal to an oxide. This will make the joint porous and brittle. An excess of acetylene is also detrimental to good work, by carbonizing the joint.



LEAD-BURNING. Fig. 5. Oxy-acetylene blowpipe flame. (1) Correct neutral flame, of medium length and pale. A represents distance of work from luminous cone for lead burning and for welding steel; B for copper, brass or bronze; and from B to C for cast-iron and aluminium. (2) Flame with excess of acetylene: it is long and brilliant, without a distinct outline. (3) Flame with excess of oxygen; it is short and pale: the inner cone is also short, with violet tinge.

A carbonizing flame will also cause a larger spreading outer envelope of flame at the extremity of the nozzle, thereby heating a larger area of lead around the joint and causing distortion of the lead. The correct flame to use is the neutral flame. Fig. 5 (1), (2) and (3) show the three different types of flame.

1 shows the neutral flame which is the correct flame to use. This is arrived at by first turning on the acetylene gas at the control valve on the blowpipe. This is followed by turning on the oxygen slowly, until a white luminous cone is formed at the nozzle point.

2 denotes an excess of acetylene, which is distinguished by a luminous outer cone.

3 denotes an excess of oxygen, which is detected by the sharp blue inner cone.

The size and width of lead-burned joints depend on the thickness and position of the metal to be burned. The table sets out general dimensions for a horizontal flat seam applicable to ordinary domestic plumbing.

C. METHODS OF MAKING JOINTS

It is necessary, especially for the student, to have a good knowledge of the various types of joints, and the preparation and procedure in lead-burning such joints. In domestic plumbing there are two types of flat seam joints, mostly used

TABLE III. DIMENSIONS FOR HORIZONTAL FLAT SEAMS

Weight of lead sheet per sq. ft.	Width to be shaved on each edge	No. of burnings recommended	Width of finished joint
4 & 5 lb.	¼ in.	2	½ in.
6 & 8 lb.	⅜ in.	3	¾ in.
10 & 12 lb.	½ in.	4	1 in.

Note.—Make allowance for lap when burning lapped seams.

on sheet lead, these being "butt joints" and "lapped joints."

Butt Joints. The two edges of the lead are fitted butt (*see* Fig. 6 on Plate *facing this page*). The edges of sheet lead on either side of the joint are cleaned by shaving to a width of ½ in. overall for 4 and 5 lb. lead. Allow ⅝ in. overall for 6 and 7 lb. lead.

No flux should be used in lead-burning.

The first operation with the flame, which should be held in the direction as shown in Fig. 7 (*see* Plate 16 facing this page) is to fuse the two edges together, ensuring penetration of the metal, at the same time adding a deposit from the lead filler rod, which is held in the left hand.

The procedure is to melt a deposit from the filler rod into the centre of the butt joint, after which, the blowpipe is moved slightly first to the right, then to the left in the line of weld. The blowpipe is lifted, and a slight pause is made before adding a further deposit from the filler rod, and the operation is repeated until the joint is completed.

The herring-bone effect is obtained by procedure control of the blowpipe as indicated by Fig. 8 (*see* Plate 16). The joint is then gone over a second time to give added strength.

Lapped Joints. The procedure for making a lapped joint is similar to the butt joint. The second burning should be as shown in Fig. 9 on Plate 16. This ensures extra reinforcement at the junction of the two sheets of lead.

Upright Joints. There are two methods of making upright joints:

1. By using the overlap of the lead as filler rod (Fig. 10 in the Plate facing this page).
2. By using a semi-circular iron mould, and building up the joint with lead filler rod.

The domestic plumber is seldom called upon to adopt the second method, as this is mostly used on lead over ⅜ in. thick, and is applicable more to chemical work.

Dealing with the former method, the lead is lapped approximately 2½ in., the underlap is shaved 1 in. past the edge of the overlap. The overlap is shaved ½ in. on either side and on the edge. The overlap is then dressed against the underlap, as illustrated by Fig. 11 on Plate 16 facing this page. A very fine flame should be used, according to thickness of lead to be burned. (*See* Table of Nozzle Sizes, page 655.) No filler rod is used, the overlap being utilized for this purpose.

Burning commences at the bottom of the seam holding the blowpipe in position, as shown by A, Fig. 11. By slightly moving the blowpipe, first melt the overlap, and almost simultaneously melt the underlap, thus causing the two surfaces to unite by fusion. The first movement of the blowpipe should deposit the lead taken from the overlap on to the underlap. The second movement of the blowpipe should come across the molten metal from the underlap to the overlap, as shown at B, Fig. 12 (*see* Plate 16), and at this point the blowpipe is lifted away from the lead.

By these motions, the lead is made to flow down off the overlap and form a bead, which is built up by repeated movements until the seam is completed. Care should be taken that the lead should not be cut in on either side of the bead as this would weaken the joint.

Another Method of Upright Burning. In this method the blowpipe is held as in Fig. 11; the commencement of burning would be at the bottom of the seam. The overlap is melted simultaneously with the underlap, and by moving the blowpipe with a circular movement, as shown by A, Fig. 12, on Plate 16, fusion of the two surfaces takes place. By this circular movement, the lead is made to flow down off the overlap and form a bead. These beads are formed one upon another until the seam is completed.

The blowpipe is not lifted after each bead is formed as in the former method, but remains on the lead until approximately 1 ft. of burning has been attained; the blowpipe is lifted and the operation repeated until the seam is completed.

Horizontal Joints. The preparation of this joint is similar to the upright joint. The lead is lapped approximately 2½ in. The overlap and underlap are shaved similarly, the edge of the overlap is turned at a slight angle from the under sheet, outwards, as shown at A, Fig. 13 (p. 657). In this instance a lead filler rod is used to reinforce the joint.

The blowpipe is held as shown by B, Fig. 13; instead of using a small hot flame a slightly larger and softer flame is used.

The flame is played across the overlap, the underlap is first slightly melted; simultaneously the filler rod is added, and the molten lead is caused to unite with the underlap and overlap, thus forming the joint. Care should be taken not to cut in the top edge of the underlap.

Alternative Method. A clever and experienced lead-burner would get strength of weld by melting down the overlap considerably, and cause it to produce strong overlapping beads without the use of a filler rod.

Underhand Burning. The lead is prepared and lapped similarly to upright preparation.

The overlap should be dressed close up to the underlap, thereby reducing the force of attraction to a minimum. The blowpipe flame should be small, concentrated and hot. The movements of the blowpipe should be circular and continuous. The blow-pipe should not be lifted after each single bead has been formed, but should remain on the seam until a minimum of 1 ft. of seam has been welded, after which the blowpipe may be lifted and the operation continued in a similar manner until the seam is completed.

The blowpipe should be held as shown in Fig. 14, the overlap being used as filler rod.

With this joint we rely largely upon attraction, which causes the two surfaces of lead to unite by fusion. The two surfaces must be brought to fluid state simultaneously, otherwise the molten lead from the overlap will fall away. When a small, concentrated flame is used, lead as thin as 3 lb. per ft. super can be satisfactorily jointed.

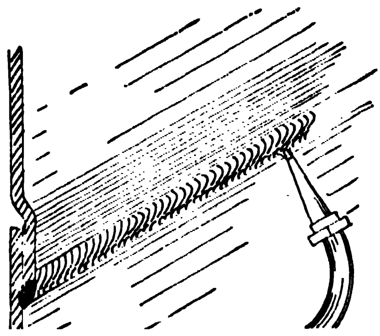
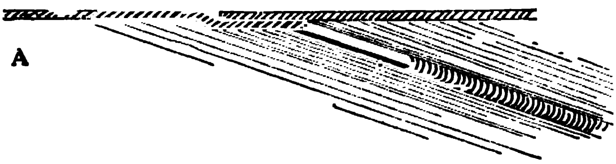


Fig. 14. Underhand burning: after thorough cleaning, the two edges are fused, the blowpipe movement being circular and continuous; if top edge of joint is cut sharp the joint is gone over a second time, using a slight excess of acetylene at blowpipe nozzle and licking sharp edge with flame.

A



B

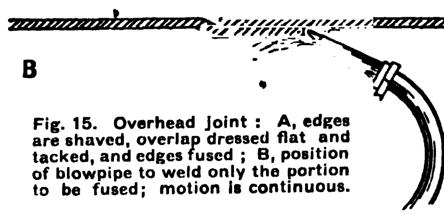
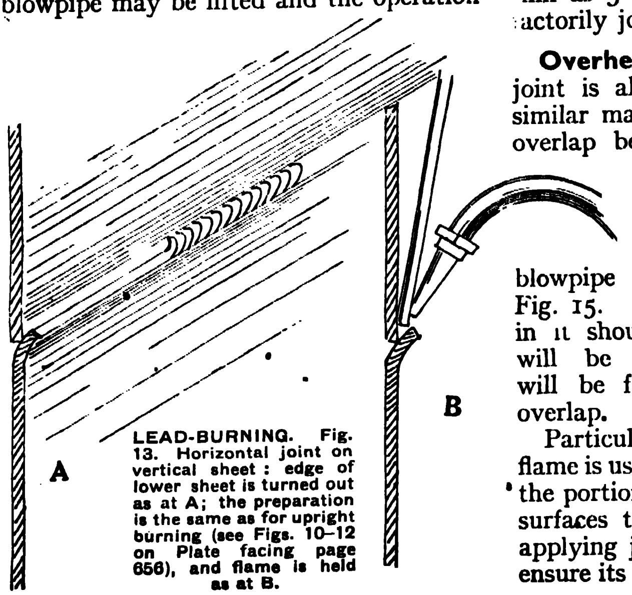


Fig. 15. Overhead Joint: A, edges are shaved, overlap dressed flat and tacked, and edges fused; B, position of blowpipe to weld only the portion to be fused; motion is continuous.

Overhead Joints. The lead in this joint is also lapped and prepared in a similar manner to the upright joint, the overlap being utilized as filler rod, as indicated by the upper diagram at A, Fig. 15.

The overlap is dressed flat against the under sheet. The blowpipe is held as shown by B, Fig. 15. A small, hot flame with sting in it should be used, otherwise trouble will be experienced by lead which will be found to melt away from the overlap.

Particularly does this occur if a soft flame is used. The procedure is to melt just the portion required to allow for the two surfaces to be fused, at the same time applying just enough heat to the lead to ensure its rapid cooling by conduction.



A

B

LEAD-BURNING. Fig. 13. Horizontal joint on vertical sheet: edge of lower sheet is turned out as at A; the preparation is the same as for upright burning (see Figs. 10–12 on Plate facing page 656), and flame is held as at B.

The blowpipe should have a full circular movement, and the movement should be continuous until approximately 1 ft. of burning has been attained, after which the blowpipe may be lifted and the movement continued until completion of seam.

Button Burning. This type of burning is met with when it is necessary to join *in situ* two pieces of sheet lead which are on an incline, and also in burning brass thimbles and ferrules to lead pipe.

With this type of burning on sheet lead, the joints can either be prepared "lapped" or "butt." The preparation is exactly the same as that used for flat burning.

A small blowpipe flame is used, and the burning commences at the bottom of the seam. The weld is produced by fusing the two surfaces of the lead, at the same time adding a deposit of molten lead from the filler rod (*see* Fig. 16 on Plate 16, *f.p.* 657). In this manner a bead is formed which is allowed to cool by lifting the blowpipe, after which another molten bath is made, adding more filler rod, and the movement is continued until the seam is completed. The blowpipe must be lifted after each bead or button is formed.

LEAD-BURNING. Fig. 18. Button joint for burning brass to lead: A, brass fittings burned to lead trap, and trap burned to waste pipe; B, brass flush pipe union jointed to lead flush pipe; C, section through joint in B. (For Figs. 16 and 17 see Plate f.p. 657.)

The overall width of this joint should be approximately ⅜ in. on 4 lb. lead. When this type of burning is done on soil or waste pipe the latter is so prepared that it can be slowly turned to allow for uniform burning.

Pipe Joints in Sanitary Work. There are several ways of jointing lead pipes together. The domestic plumber is mostly concerned in jointing soil, anti-siphon and waste piping. Water supply pipes under pressure are seldom lead-burned.

The simplest pipe joint to make is the upright bell joint. This joint, however, has limited applications for the reason that it can only be made on pipes which are fixed in a vertical position.

Upright Joint. This type of joint is prepared by belling out the end of the lower pipe to receive the abutting pipe. The end of the abutting pipe is feather-edged and inserted into the lower pipe (Fig. 17 on Plate 16).

The first operation is to fuse the bottom parts of the joint, at the same time adding metal from the filler rod until the orifice between the two pipes is filled with weld metal. The blowpipe flame is lifted occasionally during the making of this joint.

Button Joint. This joint is usually adopted when burning brass work to lead, such as brass tail-pieces to lead traps, thimbles and ferrules to soil, waste and air pipes.

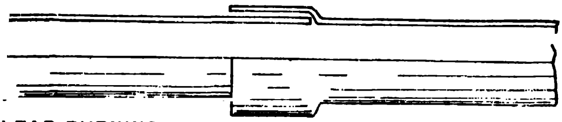
In the preparation of the joint the brass work is first tinned with a copper bit and fine solder. Resin should be used as a flux. Surplus solder should be wiped off the fitting. The end of the lead pipe is belled out to form a cup into which the fitting is inserted, care being taken to shave the inside of the lead pipe, the end of the pipe and outside the pipe ½ in. from the end (Fig. 18).

Burning commences at the top of the joint by fusing a deposit of lead from the filler rod on to the lead pipe and fitting, thereby forming a bead or button. The flame is lifted, allowing the bead to cool. The operation is repeated until the joint is completed. At the same time the pipe must be rotated. Care must be taken to see that the joint is made even and symmetrical. Preparation of the joint is shown at C, Fig. 18.

The overall width of this joint should be approximately 1 in. An alternative joint would be the upright joint.

Spigot and Socket Joint, Horizontal Joint. In the preparation one end of the pipe is opened by an expanding mandrel. This tool forms a socket which allows the end of the abutting pipe to be inserted to a depth of 1 in. The lead is shaved inside the socket, the edge of the pipe and the outside ¼ in. from the end.

The end of the inserted pipe is also shaved. Having fitted the joint, burning commences at the underside or bottom



LEAD-BURNING. Fig. 19. Horizontal spigot and socket joint; pipe prepared for burning.

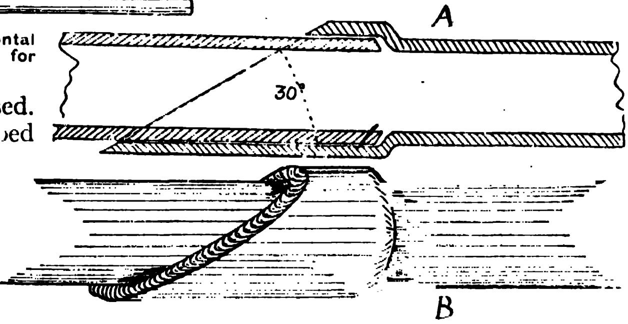
of the joint. No filler rod is used.

The procedure is as described for overhead and upright burning. Along the bottom of the pipe would be overhead burning; round the sides and top of the pipe, upright burning, the outer lead of the socket being burned to form beads around the pipe (Fig. 19).

This joint is the most adaptable for sanitary instalations, and has the neatest appearance.

An alternative method would be as shown in Fig. 20. Here the socket is cut to an angle of approximately 30 degrees from the horizontal. The only advantage is in the easier burning, less skill being required to make this joint. A shows preparation, B finished joint.

Branch Joints. Here the lead is "bossed out" by the usual plumbing methods sufficiently to form a socket to receive the abutting pipe, and the joint is made as described for spigot and socket joint, above. The branch joint is illustrated by Fig. 21 and 22, on Plate 16, *facing page* 657. The upper pipe is fitted into the socket of the lower pipe and the joint made by melting down the socket in the form of beads. A shows preparation, and B type of burning. Burning commences on the under sides. Fig. 22 shows the finished joint.



Figs. 20a and 20b. Alternative horizontal spigot and socket joint: it is made at an angle of about 30°, and is easier to burn than that of Fig. 19. A, preparation; B, finished joint.

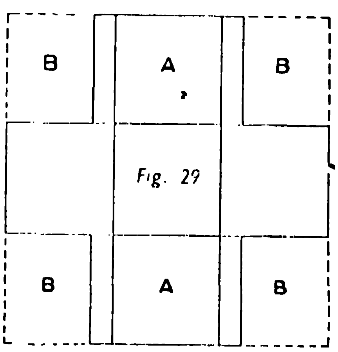
D. LEAD-BURNING FOR ROOFING AND OTHER EXTERNAL WORK

Making a Lead Slate. A completed lead slate as is used in roofing work to waterproof the section at which a pipe passes through the roof is shown in Fig. 23 on Plate 16 *f.p.* 657. The burning on the back of the upstand is seen in Fig. 24, and Fig. 25 shows the underside. The method of procedure is by forming the upstand and base from milled sheet lead.

The upstand is burned first, a flange is then formed on this section by bossing. The width of the flange should be approximately ½ in. wide. The upstand is then placed on the base at the angle desired, and burned on the flat clear of the upstand to avoid cutting in.

The slate is then turned over and the hole is next burned out with the blowpipe, using a flame with a "sting" in it. An allowance of ⅜ in. should be arranged when cutting the hole, to enable the lead to be turned up into the upstand or sleeve, as indicated by Fig. 26 on the Plate.

Making a Cesspit. Fig. 27 (*see* Plate 16) *facing page* 657 indicates how the lead is cut out and turned when making



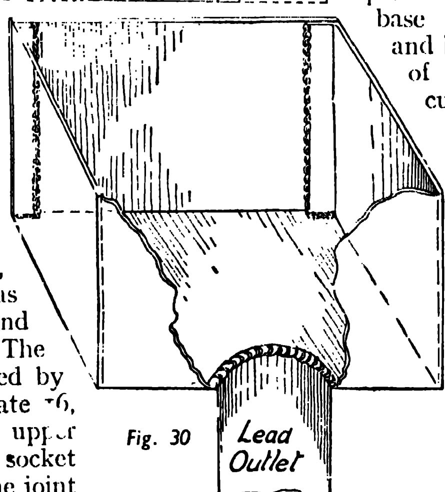
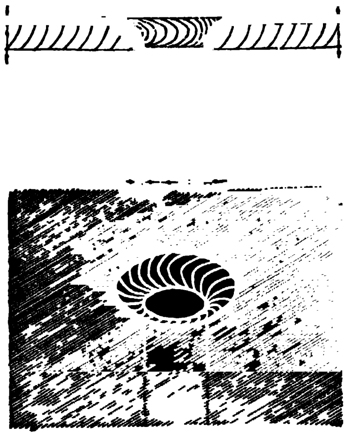


Fig. 30

Fig. 29 (top). Cesspit in lead: diagram shows lead marked out for cutting and turning. (For references see text.) An alternative method is shown by Figs. 27 and 28, on plate facing p. 657. Fig. 30 (bottom). Section of cesspit with front cut away, showing half section of outlet and burning, also upright burning on walls.

a small cistern or cesspit All the burning is done on the flat, the seam being of the butt type. Fig. 28 (on Plate 16) shows cesspit completed. An alternative method of making such a cesspit would be to set out the lead as indicated by Fig. 29 (page 659), the burning in this case being executed 1½ in. away from the angles. The lead is cut away at B and turned up as indicated at A. Position of upright seam is shown by Fig. 30 (page 659). Where all or part of the burning had to be done *in situ*, the



LEAD-BURNING. Fig. 32. Details of joint of pipe to bottom of cesspit of gutter, showing burning: (top) section through joint; (bottom) view from above. (For Fig. 31 see Plate 17.)

and burning in connexion with work entailed in the fixing of lead box gutter, are given in Fig. 31 (*see* Plate 17, *f. p.* 664); the cesspit and down pipe are self-explanatory. Fig. 32 shows jointing of pipe to bottom of cesspit. One method of "marking out" box gutters is illustrated in Fig. 33, on this page.

Set out the end of the gutter at the corners, as shown by the dotted line, allow 1 in. for the underlap, as shown at A, cut out, as shown at B, and turn up end of gutter, as illustrated

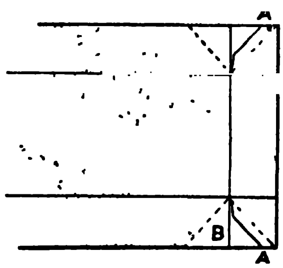


Fig 33 Setting out end of box gutter: A, 1 in. allowed for underlap; B, metal cut.

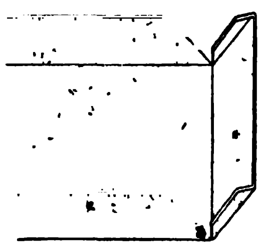


Fig. 34. Cut-out end of box gutter, half turned up.

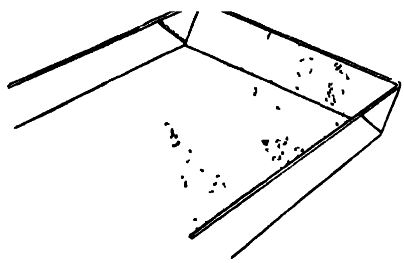


Fig. 35. Completed end of box gutter with underlap shown in Figs. 33 and 34 burned on.

upright type of burning would be utilized, using the overlap as filler rod.

Angle Burning is sometimes adopted, *i.e.* joining the lead sheets at a right angle, using lead strip as filler rod.

Box Gutters. Details of preparation in Fig. 34. The burning is done *in situ* by the upright method, utilizing the overlap as filler rod. The completed gutter is illustrated in Fig. 35.

Fig. 36 illustrates the method of "marking out" and cutting lead for drip of box gutter, and Fig. 37 shows method of turning down end of gutter and gusset piece. A gusset piece should be cut large enough to form underlap to allow for upright burning *in situ*. Fig. 38 shows completed drip.

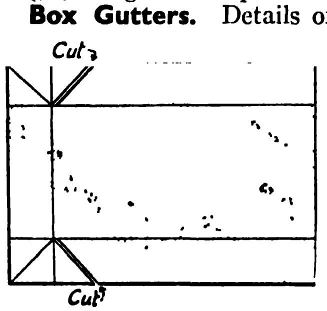


Fig. 36

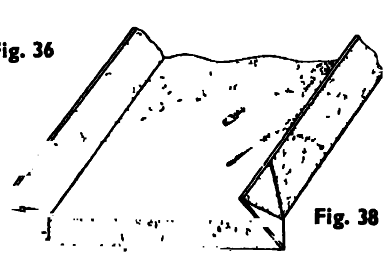


Fig. 38

Fig. 36. Marking out and cutting sheet for drip of lead box gutter. Fig. 38. Completed drip, showing upright burning on gusset.

Fig. 37

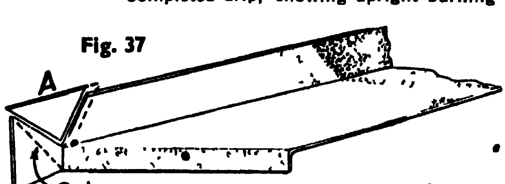


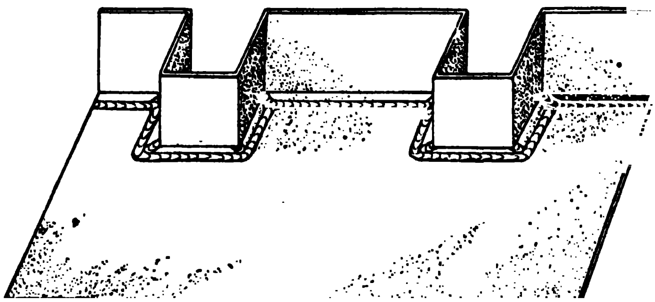
Fig. 37. Method of turning down end of gutter and placing gusset piece (A) in position for burning.

When possible to turn the gutter, all burning may be done on the flat, using lead filler rod. All joints in this case are arranged as butt joints.

Fig. 39 (p. 661) shows preparation and burning of leadwork around roof obstructions. The upstand is in one piece, and is burned to the flat with filler rod.

Internal and External Angles. Internal and external angles may be cut and a gusset piece fitted, after which the burning is done *in situ* by the upright method. (Fig. 40.)

It is necessary to allow for underlap when cutting and fitting gusset piece as shown at A.



LEAD-BURNING. Fig. 39. Burning of leadwork around roof obstructions, upstand being burned to flat with the assistance of a filler rod.

Chimney Breast. An apron flashing for a chimney breast lead-burned by inserting gusset piece is seen in Fig. 41 on Plate 17 *f.p.* 664.

Chimney Back Gutter. Lead is laid in gutter, and pieces may be fitted and burned *in situ*, as shown in Fig. 42, Plate 17. Housing estates usually fabricate chimney breast aprons and gutters, in shop on site, from template.

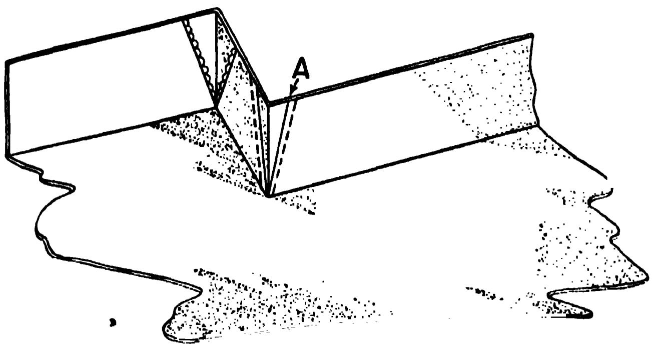


Fig. 40. Internal and external angles burned *in situ* after being cut and having gusset pieces fitted. See *also* pages 182-186.

Rectangular Rainwater Pipes. Most rectangular pipes are made from cast lead. They may also be made from milled lead. (Fig. 43, Plate 17.)

In preparation, the lead is turned and dressed round a wood former (Fig. 44). The edges of the lead are prepared as a butt joint, and shaved clean to allow for an overall finished burning of $\frac{3}{4}$ in.

Before burning commences, a thin flat steel plate countersunk in the wood former should be inserted under the joint the length of the seam to allow for penetration of the burning and smooth interior. The burning may be of the button type, but is usually of the herring-bone pattern, as shown by Fig. 6 in Plate 16, *f.p.* 656.

Plinth Bends and Offsets. In fabricating either of these, a section of rectangular pipe is utilized, as shown in Fig. 45. A V is cut, according to the angle required, as shown at A, A, Fig. 45. The length of the plinth or offset is determined by measuring the points B–B, Fig. 45.

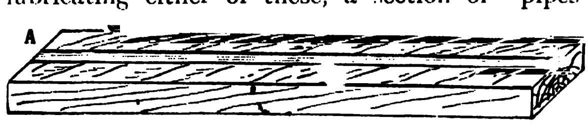


Fig. 44. Wood former or mandrel round which rectangular rainwater pipes are dressed, the seam being made in centre of iron plate countersunk in wood former at A.

The pipe should be carefully bent to form the offset, and a small soft flame used for burning.

Lead shoes are fabricated in a similar manner.

Lead heads and finials are fabricated with either cast or milled lead, and lead-burned. The burning may be of the architectural type to tone with subject, or may be cleaned off entirely. In the latter case care should be taken to get thorough penetration of weld metal during burning.

Lead Soil Pipes. External soil pipes are often made of lead, circular drawn pipe being used for this purpose. The sockets are formed by forcing an expanding mandrel

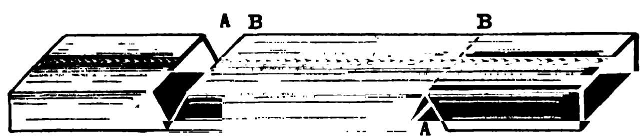
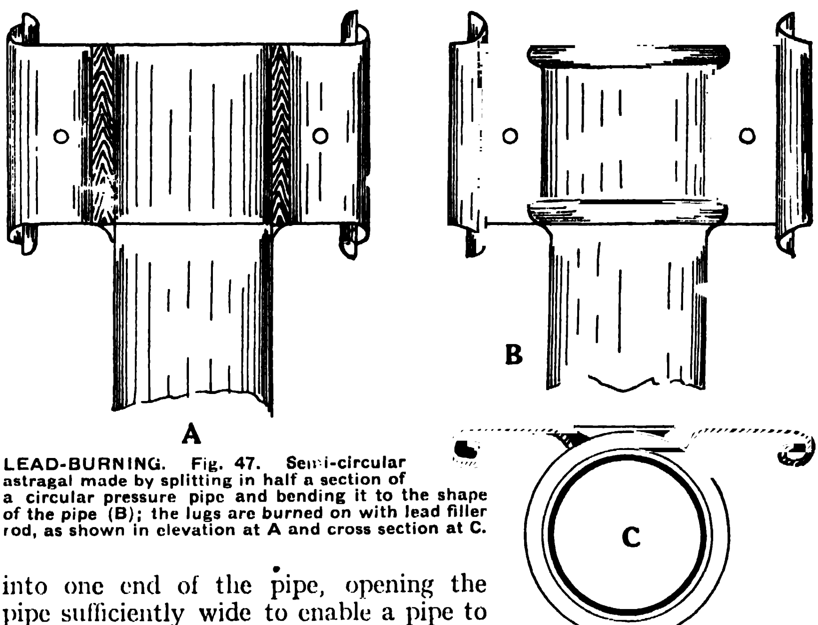


Fig. 45. Method of making plinth bend or offset from rectangular pipe: V-cuts made at A, A ; length of plinth or offset determined by measuring B–B.



LEAD-BURNING. Fig. 47. Semi-circular astragal made by splitting in half a section of a circular pressure pipe and bending it to the shape of the pipe (B); the lugs are burned on with lead filler rod, as shown in elevation at A and cross section at C.

into one end of the pipe, opening the pipe sufficiently wide to enable a pipe to be socketed into it, plus the width of the rubber ring which makes the joint gas-tight (Fig. 46, Plate 17).

Semi-circular astragals may be formed by splitting in half a piece of water pressure piping, and bending round the socket of the pipe, as shown in B, Fig. 47, above. A, Fig. 47, shows lugs burned on back of socket, using a lead filler rod.

Branch Pipes. Branch pipes are formed by the method described for spigot and socket joints, one pipe being opened out to form a socket to receive the abutting pipe, forming the branch and lead-burned by button-burning or, if *in situ*, by the method described for overhead and upright burning. Fig. 48 (Plate 17) shows branch pipe ready for lugs to be attached.

External lead soil pipes are usually connected by inserting rubber rings in the socket. At the foot of the shaft where the drain connects, a cast brass ferrule should be lead-burned to the lead soil pipe.

E. LEAD-BURNING IN INTERNAL WORK

Lead Soil Pipes. These are often used inside buildings on the ordinary sanitary system. Lead-burned joints ensure a gas-proof installation.

The spigot and socketed type of joint is most favoured, as described in page 659 (Fig. 19). All joints on pipes that can be rotated during burning would be of the button type of burning, including brass-work to lead such as thimbles, ferrules, inspection eyes, etc. Other joints having to be made *in situ* the overlap or socket lead would be utilized as filler rod, and would be as follows:

Horizontal Joints. Burning to commence underneath or at the bottom of the pipe, leftwise to top of pipe, and again from bottom of pipe, rightwise to top of pipe.

Vertical Joints. A spigot and socket is formed as described, and the overlap or socket lead is melted down to form strong beads, as shown at A, Fig. 55, in Plate 17.

Waste Pipes. The preparation and burning are similar to the method as applied to soil pipes. The angle type (see Fig. 20, p. 659) may be used on horizontal joints.

Anti-siphon and Air Pipes. The preparation and burning are similar to soil and waste pipes. Lavatory waste pipes are also prepared and lead-burned similarly as described, except where the pipes have to be jointed close to the floor in a horizontal position *in situ*. In this instance it is not possible to burn on the outside underneath the pipe, and what is known as a split joint has to be made. The preparation of this joint is as follows:

One end of the pipe is opened by an expanding mandril a distance of 2½ in. to give room to socket the other end sufficiently. The socket is then cut open longitudinally and across the top of the pipe, as shown by Fig. 49 in Plate 17.

The other end of the pipe to be inserted in the socket is cut on the "splay" at about 45° and fitted into open end at point A, Fig. 49. Burning commences at the bottom half of the inserted pipe, from A to B, Fig. 49, then continues from B to C. At this point burning changes

from internal to external, and is continued on the outside of the pipe, the worker having first pressed the two sides over the internal pipe. Having burned the four seams, the joint is completed by burning the flat butt seam on the top of the pipe. Completed joint is shown in Fig. 50, Plate 17.

Internal Lead Floor. A detail of lead-burned floor and gutter to shower and spray room is given in Fig. 51 on Plate 17, *f.p.* 665, and is self-explanatory. It will be noticed that the angles and upright joints are capped. The lead at the back of the capping is fitted to butt. Cesspit details are shown in Fig. 32, p. 660.

Making Y Branch. Part of the two outer curves of two lead bends are cut away to the centre line, as shown in Fig. 53 *see* Plate f. p. 665. The cut edges are then butted together, spot-tacked in position using lead filler rod, and the joint is completed by method stated for button burning, the blowpipe being lifted after each application of filler rod. Fig. 52 (in Plate) shows alternative method of preparing and burning Y branch (button burning).

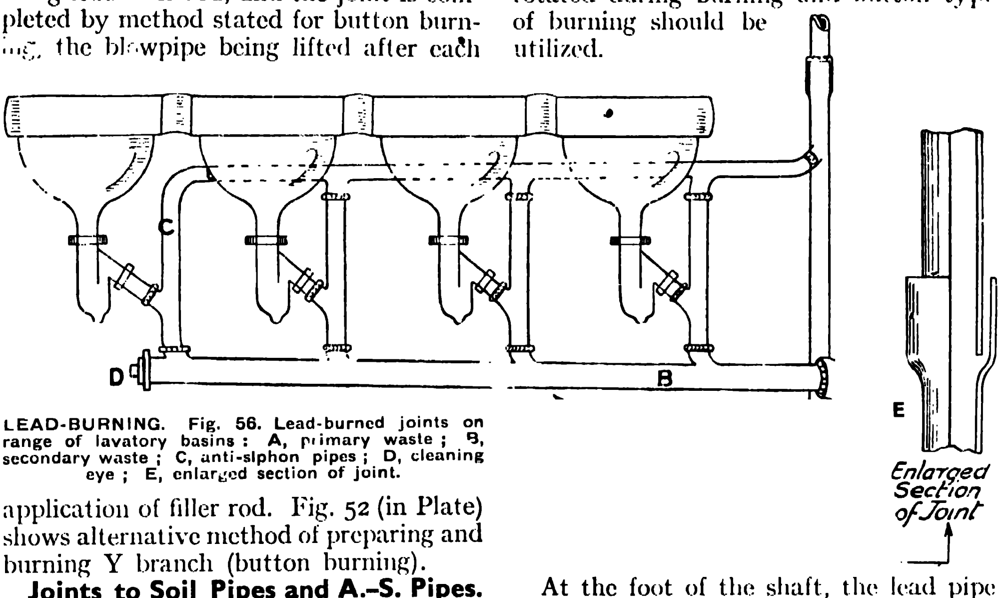
Joints to Soil Pipes and A.-S. Pipes. Fig. 54 (Plate 17) gives an idea how lead soil pipes are prepared and lead-burned. A shows section of main soil stack in cast iron; B, brass sleeve to lead pipe; D, lead pipe; C, lead-burned joint connecting brass sleeve to lead pipe; E, lead-burned joint; F, brass thimble connexion to w.c. basin; G, socketed lead-burned joint made *in situ*; H, lead anti-siphon pipe.

Lead pipe should pass through brass sleeve B, and button-burning method should be adopted to make joint.

Fig. 54A (*see* Plate) shows joints to cast-iron soil pipe, A. B is brass thimble; C, lead-burned joint; D, lead anti-siphon pipe. B is also shown in enlarged section at side. Cast iron joints are made with caulked gasket and molten lead.

Fig. 55 (*see* Plate) shows section of lead soil and anti-siphon pipes. An expanding mandrel is used to form the sockets on one pipe. To receive the abutting pipe, as shown at A, the joint is made by burning down the overlap in the form of strong beads, no filler rod being required. The anti-siphon pipe, B, may be inserted into the soil pipe by either forming a socket similar to A, or inserting the abutting pipe 1 in. into the bossed out section of soil pipe, as shown in sketch. The type of burning is the same as for A.

The brass thimble, C, should be prepared as previously stated and burned on to the lead pipe previous to the joints A and B being made. The pipe should be rotated during burning and button type of burning should be utilized.



LEAD-BURNING. Fig. 56. Lead-burned joints on range of lavatory basins: A, primary waste; B, secondary waste; C, anti-siphon pipes; D, cleaning eye; E, enlarged section of joint.

At the foot of the shaft, the lead pipe should pass through the brass ferrule or sleeve. The joint may be of the button type of burning by rotating the pipe, or if the pipe is *in situ* as described for A using lead filler rod in each instance to make joint.

Range of Lavatory Basins. Fig. 56 illustrates lead-burned joints to waste and anti-siphon pipes. A, denotes primary waste pipe. B, secondary waste pipes. C, anti-siphon pipes. D, cleaning eye.

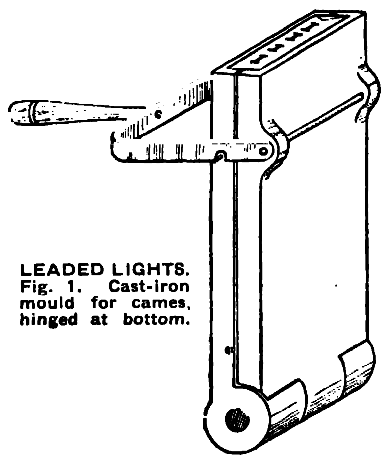
The type of preparation and jointing would be as shown in enlarged section, E.

LEADED LIGHTS: MAKING AND REPAIRING

By Percy Manser, M.R.San.I., R.P.

The repairing of leaded lights is done by plumbers in rural districts, together with sundry glazing work. Occasionally the worker is called on to make up lights, and the information here provided will enable him to undertake such jobs. For further hints on soldering, see Soldering.

Lead-light glazing is the formation of glazed lights of various patterns which are built up with lead "cames" and small pieces of plain or coloured glass. At one time glazing formed part of the plumber's training, and even at the present time in many districts the plumber still has some connexion with glazing in one form or another. The making of leaded lights is now executed mainly by specialist firms, but the plumber is often called upon to make them or to repair or replace lights which have become broken or damaged. The "cames," or "calmes," are in effect the glazing bars in which the glass is held. They are composed of lead strip which in section is in the form of the letter H and varies in size according to the nature of the job; they can be obtained from lead manufacturers, but if a mould and hand mill form part of the shop equipment they easily can be made by the plumber.



LEADED LIGHTS. Fig. 1. Cast-iron mould for cames, hinged at bottom.

Making the Casts for Cames. The mould (Fig. 1) is of cast-iron and made in halves hinged together at the lower end. A wood handle is fixed to a hinged iron loop which passes over the top end and clamps the halves together while the lead is poured in. The mould should be well heated before pouring in the lead, as the casting space is very small. Like the finished cames, the casts are of H section but much thicker; to finish them they are passed through the came machine in which are fixed formers or cutters and milled edge wheels to suit the type of came required.

As the handle is turned, the wheels grip the heart of the cast came and draw it through (*see* Fig. 2), while the cutters on each side form the shape of the outside of came. It is considerably lengthened during the process, and to assist its passage through the machine a little lard-oil or similar lubricant should be smeared on the casting. As the finished came issues it should be cut to suitable working lengths and carefully placed on a board or in a box, as it is easily twisted and damaged.

The cleaner cames are kept, the easier will be the job of making or repairing

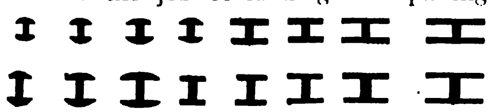


Fig. 3. Types of came, shown in cross section.

lights. The machine should be securely bolted to a solid bench, as the leverage on the handle is considerable and turning it is not an easy job. The main principle of the machine is shown in Fig. 2. The spindles are operated by small cogged wheels and cutters are fixed in recesses in framework. Many types of cames can be produced, to suit different thicknesses of glass and the size of the light to be made. A few are shown in Fig. 3.

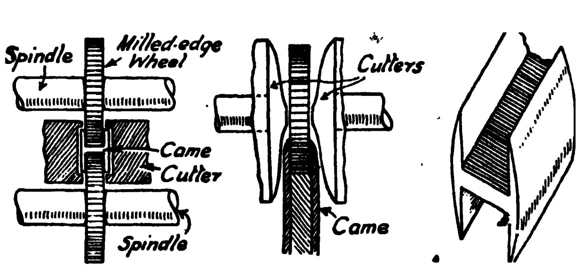
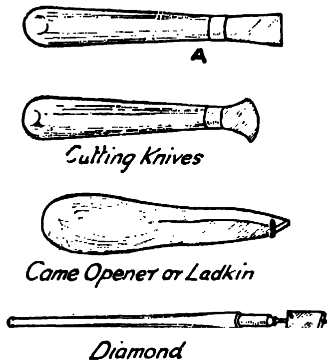


Fig. 2. Came machine: left, came in position for cutting; centre, came at point of entry, with wheel gripping it; right, portion of finished came.

Tools for Leaded Lights. For lights, tools required are: Glass cutters, diamond and wheel type; tee square and cutting laths; straight-edges; glazier's pliers, cutting



LEADED LIGHTS. Fig. 4. Tools for making lights; knife A made from broken chisel knife.

pliers; tack hammer, cutting knife, came opener, putty knife, copper bit. A gas-heated copper bit is a useful tool for this work. A came opener, or "ladkin," is best made of bone or horn (such as an old, large, knife handle), but an odd piece of boxwood (a broken dresser or bossing stick) will make a handy tool. The knife shown at A, Fig. 4, was made of a broken chisel knife sharpened to a fine cutting edge; it proved useful for cutting and skiving the cames. A straight-edge bevelled to enter the came as at E, Fig. 7, is useful for tapping the squares or quarries into position as the work proceeds (see F, Fig. 7).

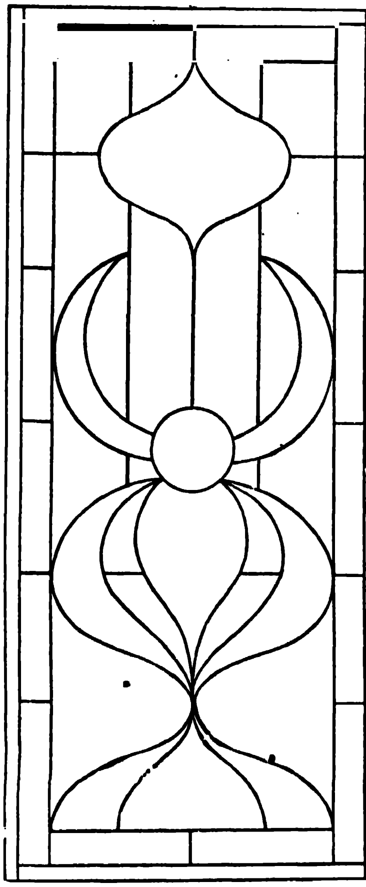


Fig. 6. Ornamental panel, for which a working drawing must be prepared.

Making the Lights. A perfectly flat surface is essential on which to build up the numerous pieces of which the lights are formed. For plain, straightforward lights, the measurements of the opening and the size of the squares or quarries only are necessary; but for intricate designs (such as Fig. 6) a drawing must be prepared. If coloured glass is to be included this can be indicated by crayons, and the cames with a very soft lead or a charcoal pencil. For small lights the pattern can be fixed to a board similar to an ordinary drawing board. The drawing can be held in position by the guide laths.

Let Fig. 5 represent a plain rectangular light of 12 squares or quarries. The type of came having been decided, set out the job, allowing for the thickness of the hearts of cames, and then cut the glass to size. Before using the cames, cut suitable lengths for the job and stretch or "kill" them. Hold one end in a vice, grip the other end with pliers and pull gently but firmly until perfectly straight. Lay the lengths on a board until ready for cutting to the exact size. Tack a lath on the board or bench, and another at right angles, as A and B, Fig. 7. These will represent the bottom and side of the opening for the light. Cut to length the rebate or margin cames, and tack to the board against the laths, as C and D, Fig. 7. These cames will be wider than those used between the quarries for fixing

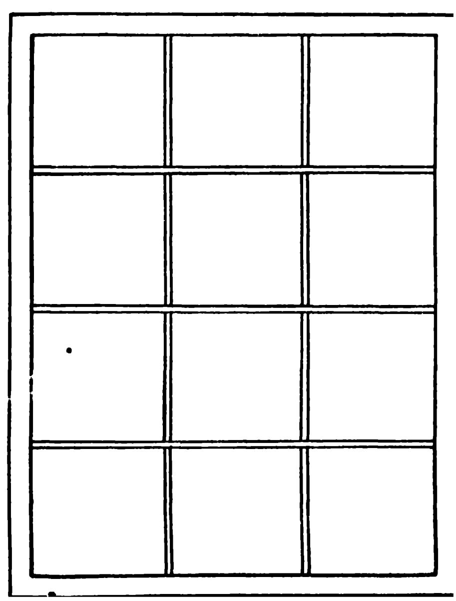


Fig. 5. Plain rectangular light of twelve quarries. For method of making, see text and Figs. 7 and 8.

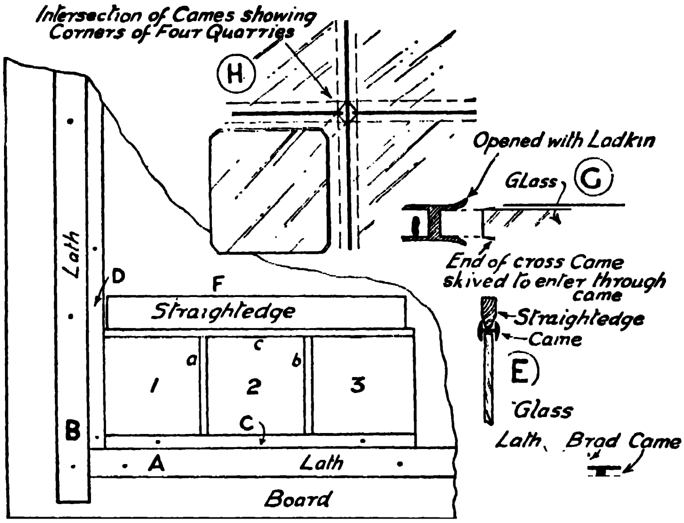
purposes, and should be wide enough to project beyond the rebate, as in Fig. 9.

Run the opener or ladkin along these cames to spread them for the glass. Cut the short cames the exact length or width of the glass, and skive the ends as shown at G, Fig. 7. The long or through cames will be cut as required: in this case equal in length to three quarries plus two hearts of cames. The ends are skived to enter the rebate cames.

Commence with square No. 1 (*see* Figs. 7 and 8): slip in cross came *a*, then square 2, cross came *b*, next square 3. The through came C is then placed in position, and to make sure the three pieces of glass are "home" in rebate came C, the straight-edge is placed in the through came and gently tapped with the hammer, or other suitable tool at hand. The same operation can be carried out from square No. 3 towards rebate came D, and if desired a temporary lath placed (as shown at E, Fig. 8) to keep the work in position. The remaining squares are placed in position in the order shown in Fig. 8, and another lath may be tacked outside the top rebate came (as at F) to hold the job secure while soldering. Before the squares are placed in position the corners should be nipped off with the pliers, as at H, Fig. 7.

The cames are then rubbed or closed down to the glass with a closing knife, which is similar to a putty knife; or a thin bone tool answers the purpose very well.

Soldering the Cames. The next job is to solder the intersections of the



LEADED LIGHTS. Fig. 7. Making a simple light: A and B, laths tacked on board; C and D, rebate or margin cames; E and F, came held between glass and straight-edge; G, cross came skived for insertion into through came; H, intersection of cames. Small letters and numbers correspond with those in Fig. 8.

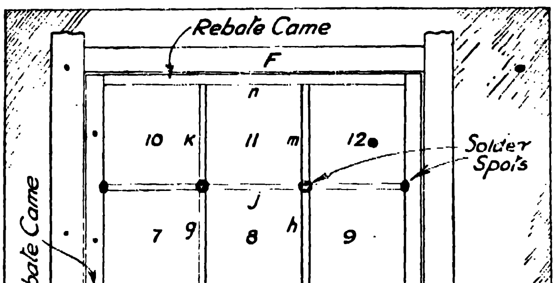


Fig. 8. Simple light of Fig. 5, with cames placed in position by method shown in Fig. 7 and described in text.

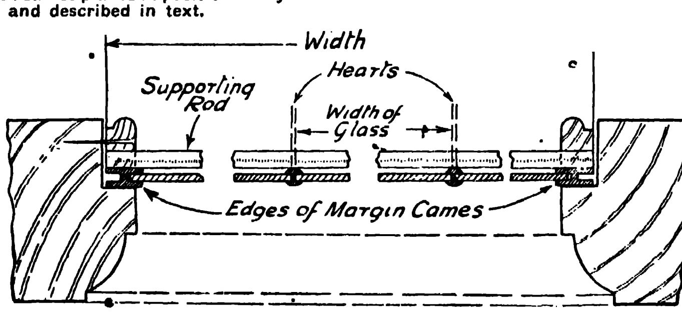
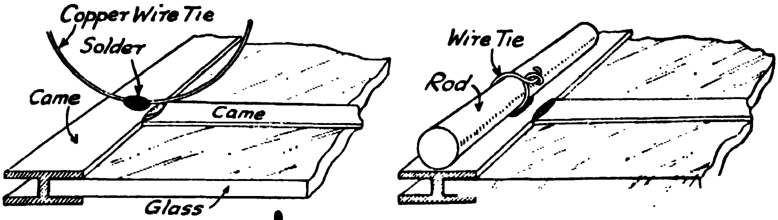


Fig. 9. Setting out came for light of Fig. 5; margin cames (C and D of Fig. 7) are cut wide enough to project beyond rebate.



LEADED LIGHTS. Fig. 10. Fixing rod supports to back of lights: (left) wire tie soldered to came; (right) rod tied with wire.

cames. Copper-bit or blowpipe solder is suitable, and the latter makes a very neat "spot" or "button." A flux of finely powdered resin and a little tallow is quite good, or use may be made of "Fluxite" paste. The copper bit must not be too hot, or melting of the cames may easily occur, with ugly results. It is for this reason that a gas-heated iron gives good results: the flame can be regulated to obtain an even heat. One side completed, the light is turned over; the other side is rubbed or closed and then soldered.

Cementing the Quarries. The final job is to fill or cement the quarries to the cames. Thick paint or a mixture of whiting, linseed oil and vegetable black is generally used, being worked in with a wad of rag or a stumpy brush. Dry whiting, applied with a rag, is used to remove surplus paint or filling, and a final rub is given with dry black. If properly cleaned, the solder spots will show up brightly, while the cames will be clean but dull in comparison.

Supports. To give support to lights, iron or copper rods may be fixed to the back of them. The rods are of $\frac{1}{4}$ in., $\frac{5}{16}$ in. or $\frac{3}{8}$ in. round section, according to the size of the light. Copper wire ties are soldered to the cames at intervals; these are twisted round the rod as shown in Fig. 10, and the ends of rod secured in the rebate of the opening. The light shown in Fig. 12 measures 27 in. × 12 in., and is provided with two cross stays or supports as shown. These supports should, wherever possible, be masked by a through came, so as not to spoil the effect of the design.

Repairs. The repairing of leaded lights is a tedious job, unless they can be taken out and the work done on a bench. Minor repairs, such as the replacement of a

Fig. 11. Replacing a pane of glass: came is cut at corners, flange lifted as shown, glass replaced, and flange rubbed down into position.

broken square or two, can be carried out *in situ*, but a great deal depends on the condition of the light and the type of came as to whether even one piece of glass can be successfully replaced. It is an easy matter to remove the broken glass, but the replacement means that the cames must be cut at the corners, the "flange" or "lip" lifted to get the glass in, and afterwards rubbed down again (*see* Fig. 11). With narrow cames it is very difficult, as there is little lead to lift and it usually curls up and breaks at many points. With the wider cames, if the lead is in good condition, lifting can be successful for the replacement of broken glass.

If the damage is at all serious, it is quicker and more economical to take out the light, so that cames can be cut out, if necessary, for making a sound job. Repairs, should, if possible, be effected from the back of the light, so that cut or otherwise damaged cames which must be soldered are not plainly visible.

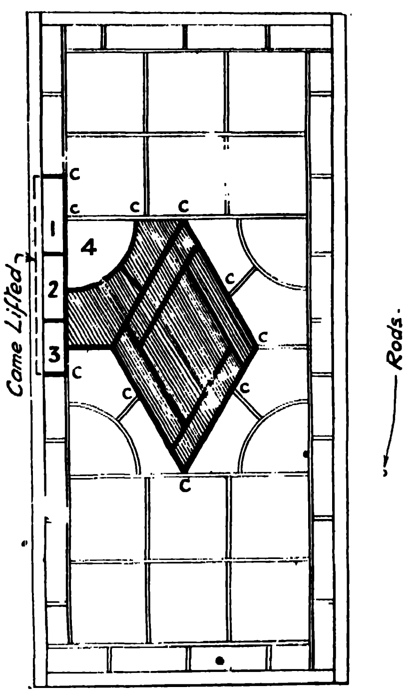
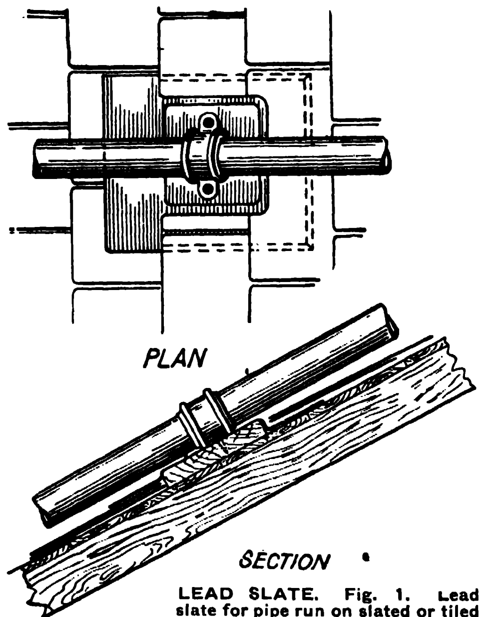


Fig. 12. Repairing door panel: shaded portion and squares 1, 2, 3, 4 removed; cames cut at points C.

Fig. 12 is given to show how a repair was effected. The light was taken out and the shaded portion (which was smashed) was completely removed, together with the pieces numbered 1, 2, 3, 4, and the cames shown in heavy lines. These cames were neatly cut at the points



LEAD SLATE. Fig. 1. Lead slate for pipe run on slated or tiled slopes. Slate is formed of sheet lead on wood block fixed to rafters.

marked *c*. The rebate came was cut and lifted as shown by the dotted line. Glass of the desired tint to match the remainder was obtained, cut and fitted into new cames as indicated, and the pieces 1, 2, 3, 4 refixed. The points where the cuts were made were afterwards soldered in the usual way. The cames in this case were $\frac{3}{16}$ in. wide, and it was quicker to remove the sound squares or quarries 1, 2, 3, 4 and the cames than to try to replace the shaded portion, otherwise it would have been difficult to leave a sound job.

Cutting Curved Patterns. When making up or repairing lights similar to that shown in Fig. 6, useful curves for the purpose can be made from stout cork linoleum, or from plywood. For work on a large scale, a compass diamond should be included in the equipment. For temporary use an odd piece of lino. can be cut with a sharp pocket knife to the desired curve.

LEAD SLATE. This term has two applications: (1) a piece of sheet lead shaped to make a weather-proof joint where a pipe passes through a sloping roof of slates, tiles, etc. (*See* Figs. 2–5; also illustrations under Lead-burning.) (2) A lead-covered piece of board fitted to a slated or tiled roof for fixing lead or iron soil, waste or vent pipes. (*See* Fig. 1.)

The first-named are made in various ways. (*a*) Bossing them from sheet lead. (*b*) Using a piece of lead pipe and soldering or burning it to a flat piece of lead. (*c*) Making a pipe from sheet lead, soldering or burning the seam, and joining the pipe

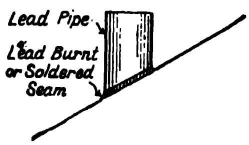


Fig. 2. Slate formed by soldering or burning.

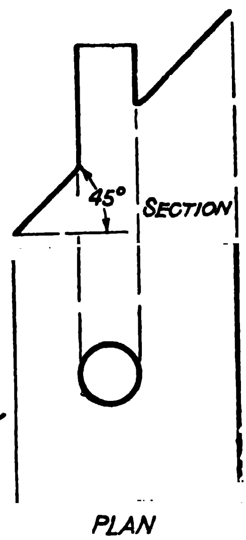


Fig. 3. Plan and section of lead slate shown in Fig. 4.

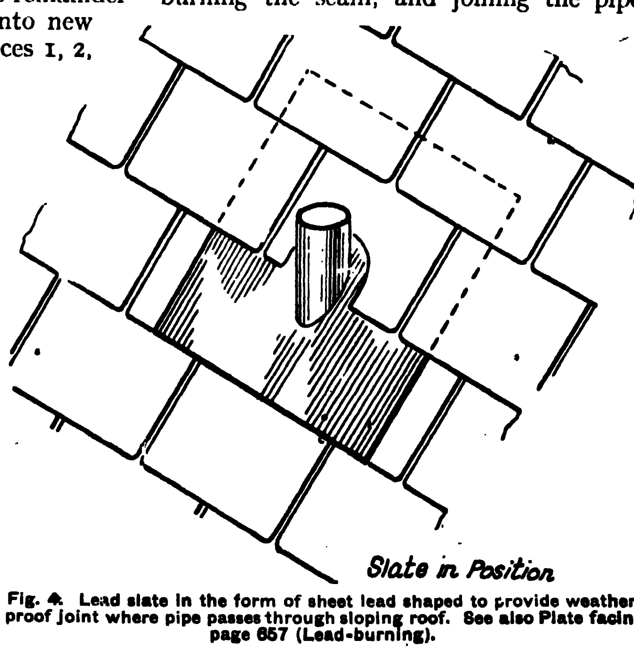
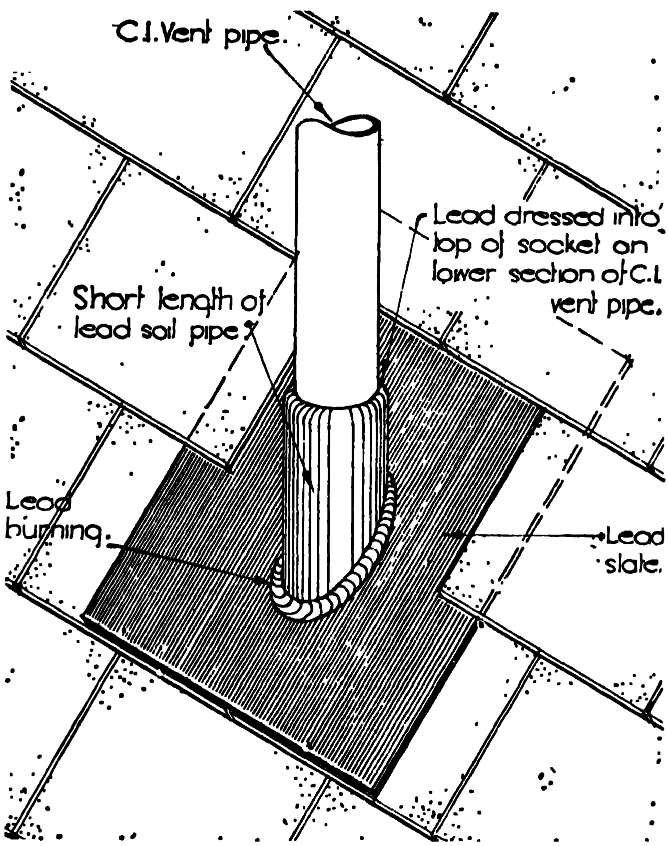


Fig. 4. Lead slate in the form of sheet lead shaped to provide weather-proof joint where pipe passes through sloping roof. See also Plate facing page 657 (Lead-burning).

to a flat piece by one of these methods. These are for iron pipes. If the pipe passing through the roof is lead, it only requires a piece of sheet lead fitted around it, and made weather-proof by wiping a flange joint.

Where iron pipes are concerned, various methods are used to make a sound joint between the pipe and the top edge of the tubular portion of the slate. A common method is to squeeze oil cement in between the iron pipe and the slate, and to dress the lead tightly to the iron. Another method is to arrange the piping so that a socket is just above the roof line, and dress the top edge of the lead tightly into the neck of the socket; or to turn the lead over the top edge of the socket so that it is incorporated in the caulked joint made for the next length.

Slates for fixing pipes on roof slopes are formed by fixing a block of wood to the rafters or boarding, and covering it with sheet lead so that it stands a little above roof line (*see* Fig. 1). The flat portion of the lead must be large enough to form proper laps over and under the slates or tiles.—*Percy Manser, M.R.San.I.*



LEAD SLATE. Fig. 5. Lead slate to cast-iron vent pipe, with short length of lead soil pipe burned on sheet. *See also* Plate facing page 657 (Lead-burning).

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LEAD WOOL. Thin strands of lead in the form of a hank or skein, used for caulking joints in place of molten lead. Lead wool is a useful material for making caulked joints on cast-iron socketed pipes, especially when such pipes are being laid in wet surroundings or during wet weather. The danger to the worker which may arise from pouring molten lead into a wet caulking space is thereby avoided. No lead pot, fire, ladles, caulking clamp or clay bands are required.

The fine strands of lead are twisted together similarly to a skein of ordinary wool. They can easily be separated and cut to a suitable length and bulk for feeding into the caulking space, where they are gradually consolidated with the caulking tools and hammer until the space is completely filled. *See* Caulking Tools; *also* Joints: (2).

LEADWORK: Creeping. The ease with which a metal can be worked or "bossed" is a measure of the "plastic deformation" that can occur under the combined influences of external force and applied heat. During bossing, lead readily alters shape because of an easy "flow" of the crystals over each other, an action greatly assisted by heating.

In warm weather, when it is unusually plastic, leadwork on roofs is subject to the internal stress of expansion due to sun heat, in addition to an ever-present tendency to slide downwards because of its own weight. Under these combined forces of expansion and gravity there must be movement which, since the lead is necessarily fixed at the higher end, can only take a downward course. This may be followed in a few hours by a temperature

drop of perhaps 60° F. or more (say 110° F. sun temperature to 50° F. night temperature), which must cause the lead to contract. But for its great weight, contraction might draw the metal up the slope again, but it is much more likely to draw more metal downwards, bearing in mind the assistance of gravity in that direction. When this process has been repeated daily over a period of months and, in time, years, it is reasonable to expect some degree of " creeping " in lead so affected, due to its progressive downward movement and repeated nonreturn to the position occupied before expansion. In many situations the great ductility of this metal leads also to stretching under sun heat and gravity, an action which can only worsen matters and hasten failure due to creeping.

It is clear that concealed tacks and fixings can do little more than hinder the action. On flats and similarly easy slopes, frequent drips (*which see*) shorten the lengths of lead required, and so reduce the total expansion and weight of each piece. It is also necessary that the slope be as easy as possible in order to minimize the sliding tendency. On greater slopes, such as domes and spires, the use of small bays is again of primary importance for the same reasons.

A " herring-bone " or other ornamental arrangement of well under-cut wooden rolls is of considerable advantage in supporting each bay without undue dependence upon concealed tacks.—*J. W. Cowan, A.M.I.H.V.E.*

See Expansion : in Lead Roofing ; Roofwork : in Lead.

LEADWORK : ORNAMENTAL WORK IN CAST AND SHEET LEAD

By Percy Manser, M.R.San.I., R.P.
Instructor in Plumbing at the Tottenham Polytechnic

Under the heading Cast Leadwork earlier in this work Mr. Manser gives instructions for simple ornamental work, and the reader should refer there for useful details. In the present contribution ornamental work in cast, bossed or built-up lead is dealt with. Instructions are given for making rainwater heads, pipes, vases and bowls, flower boxes, finials and curbs, while a section is included on embossed work. A folding Plate faces page 672. See *also* Lead-burning ; Rainwater Pipes and Heads (Lead).

Ornamental leadwork includes such items as gutters, rainwater heads, rainwater pipes, vases, fonts, bird baths, sundials and cisterns ; coverings to ridges, hips, domes, cupolas, turrets, torus rolls, finials, fascias, spandrils, and also linings and fronts for window boxes.

Cast lead, milled lead or a combination of both may be used for the make-up of many of these items. Ornamental work in cast lead was executed to a very large extent centuries ago, and many fine examples of early cast leadwork are still to be seen in many parts of Britain—not only in museums and similar places as exhibits of craftsmanship, but still carrying out the purpose for which they were made and fixed. At Hampton Court may be seen lead-covered cupolas to the turrets, and also lead vases of excellent design. Sir Christopher Wren made great use of lead for covering the spires and cupolas of his City churches, and the dome of St. Paul's is an example. Fine examples of statuary still exist in many districts, and cisterns with various forms of decorative panels, coats of arms and monograms are fairly numerous. At Knole, Sevenoaks, may be seen some excellent examples of leadwork in the form of rainwater heads, pipes and also cisterns.

RAINWATER HEADS

The advent of leaden rainwater heads and their accompanying down pipes took place about the end of the fifteenth century, when they were introduced to take the place of gargoyles (*i.e.* ornamental spouts fixed to conduct the water beyond the wall face). The plumbers of that time were thus enabled to exercise their practical ability in the general arrangement of heads and pipes for the conveyance of rainwater from roofs. Many elaborate rainwater heads were designed and made, and cast ornament was extensively used as a decorative medium. There are numerous lead heads still in use, and in addition to the highly elaborate and exclusive designs to be found there are

LEADWORK : ORNAMENTAL. Figs. 1 and 2. Bossing a rainwater head from milled sheet : (left), commencement of work ; (right), bossing the lead to form the cone.

many of a stock type. Eventually, lead gradually fell into disuse and the substitution of iron on account of its cheapness gave rise to a deplorable laxity in the matter of design ; cast-iron rainwater heads and pipes became merely something to conduct the rainwater from the roof. It has, however, been recognized that iron cannot compare with lead for durability or adaptability, and lead does not require periodical painting to preserve it.

Fig. 3. Milled sheet formed into cone, at conclusion of operation shown in Fig ? above.

Head Bossed in Milled Lead. Milled lead can be bossed into many intricate designs without the use of moulds or blocks, and patterns can be worked to an architect's drawing if necessary ; but in many cases cast lead is considered more suitable for making up rainwater heads. With modern lead-burning equipment the making of heads and pipes with either cast or milled lead is simplified.

The method of bossing a head from milled sheet varies, but Figs. 1, 2 and 3 show three stages during one process. The lead is first worked up into a cone shape, and when sufficiently advanced the back is formed and the outline of the head bossed roughly into shape. As the job proceeds the lead is worked to the desired pattern, and the method to be followed depends upon the actual finish—*i.e.* whether a moulding or ornamental edge is to be bossed as an integral part, or made separately and soldered or burnt on. The head shown in Fig. 4 was bossed from 6-lb. lead, the rope pattern edging being formed around the top with chase wedges. The lugs or tacks were cut from 7-lb. soil pipe, the moulded edge being ½ in. × 30 in. lead pipe cut down the centre ; the pattern was chased in with a sharp boxwood wedge, the corners mitred and burnt on to the 7-lb. lead from the back.

The rosettes or bosses for the nails were cast in sand in an impression made by an old brass rosette ; these were also burnt on from the back. To give extra strength

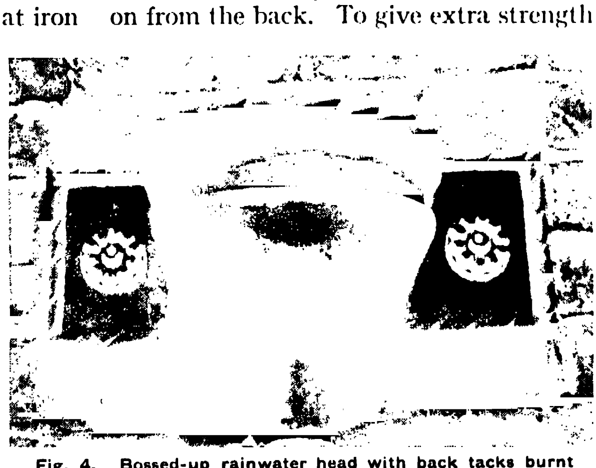
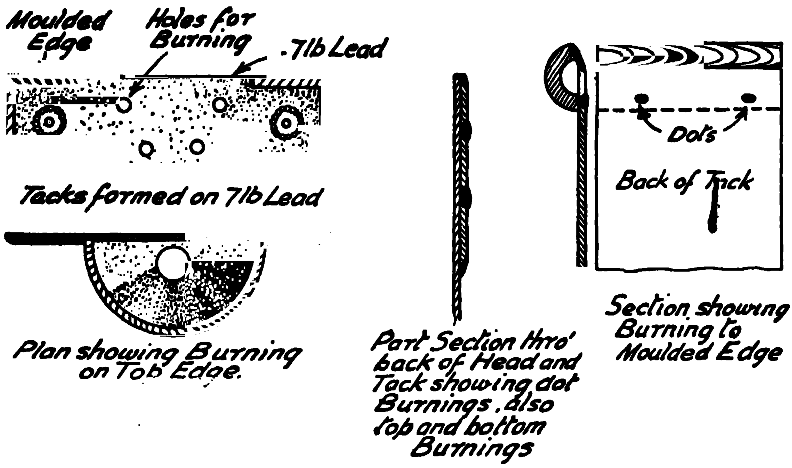


Fig. 4. Bossed-up rainwater head with back tacks burnt on : head made from 6-lb. sheet, and lugs from 7lb. soil pipe.



LEADWORK : ORNAMENTAL. Fig. 5. Making up rainwater head : tacks were built up on strip of lead passing across back of head, and strip was burned at top, bottom, and each side of head, with four dot burnings to back of head.

to the job the tacks were built up on one strip of lead passing across the back of the head ; the strip was burnt along top, bottom, at each side of head, and 4 dot

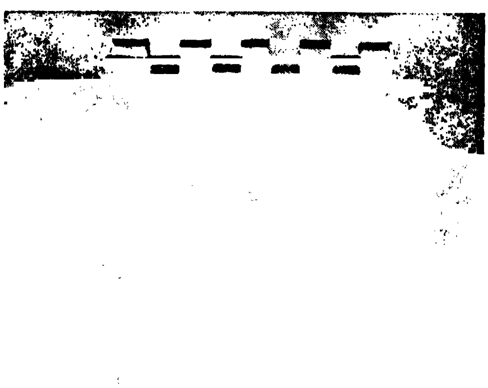


Fig. 6. Built-up rainwater head ; main part of body bossed from milled sheet ; moulding cast and burnt on.

burnings were made to back of head (Fig. 5). A chalk sketch on brown paper was used as a working drawing.

Built-up Head. A built-up head is shown in Fig. 6. The main part of the body was bossed from milled sheet ; the castellated moulding was cast in sand in an impression made by wood moulding, and afterwards mitred and burnt on. The tacks are the ordinary cast stock pattern, also burnt on to the head. The monogram was cut from stout sheet lead and fixed by secret soldering.

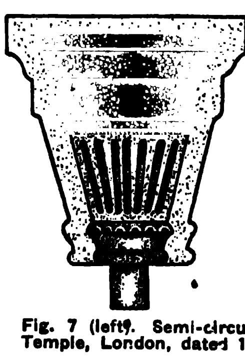
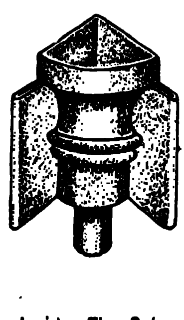
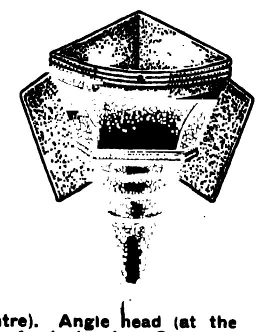




Fig. 7 (left). Semi-circular head. Fig. 8 (centre). Angle head (at the Temple, London, dated 1678). Fig. 9 (right). Angle head at Somerset House, London.

Simple Bossed Head. A simple and inexpensive type of head which can be formed by bossing, having ears or wings soldered or burnt on, is shown in Fig. 7. The making of a head of this type can be simplified by bossing the front from one piece and then cutting the back and ears from another piece, soldering or burning them together. If this is done it is advisable to allow an inch on the front for turning on to the back. This is a type for which a mould could be used if a number are required.

Angle Head. An angle head with a bell-shaped front is shown in Fig. 8. This is fixed in the Temple, London, and was made in 1678. The front is soldered to the back ; the lugs or rings are soldered on, and the outlet pipe is soldered to the bottom. The head is fixed by wall hooks, the lugs being made long enough to fold back and cover the heads of the hooks, in the same manner in which lead soil and rainwater pipes were fixed before the introduction of cast lead tacks. This method is described because from a distance it may be a matter of conjecture to the uninitiated as to how they are fixed.

Another angle head having a bell-shaped body is shown in Fig. 9 ; many of

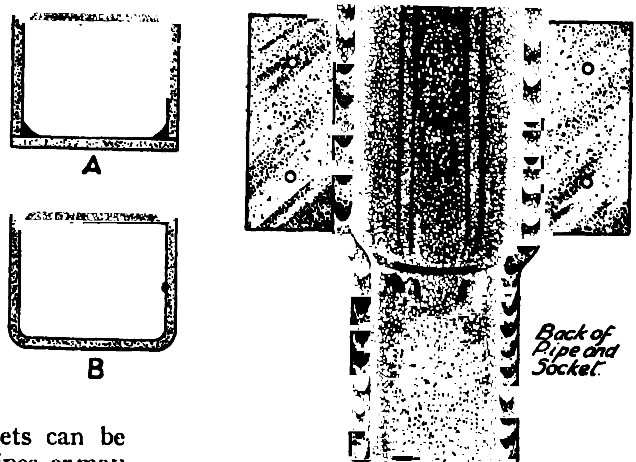
these are fixed on Somerset House, London. It is made on similar lines to Fig. 8, fixed in the same way.

RAINWATER PIPES

Modern lead rainwater pipes may be of cast lead or be made up from lengths of hydraulic-drawn lead pipe, which can be obtained in various sections to suit different styles of architecture. Sockets for such pipes may vary in length from 3 to 6 or 9 ins., to suit the shape and size of the pipe. These sockets can be formed by the plumber on the pipes, or may be made separately and afterwards burnt or soldered on. Tacks also may be cast or made up from stout cast or milled sheet and be burnt or soldered on.

Cast pipes vary in the way they are made up, and ornamental features which are required are usually cast together with the pipe, the sockets and lugs being afterwards burnt or soldered on.

Made-Up Pipes. Made-up pipes which may be required with sharp arrises are formed of four strips, the front and the sides being burnt together first on the inside, and the back burnt on last, as shown in section at A, Fig. 10. If rounded angles are required on the front the pipe is made up in two pieces, the back being burnt on as before described and the front and sides being in one piece, as in section at B, Fig. 10.



LEADWORK: ORNAMENTAL. Fig. 10. Made-up rainwater pipe, shown in section and from the back: A, four strips burned together to give sharp arrises; B, two strips used to give rounded front angles.

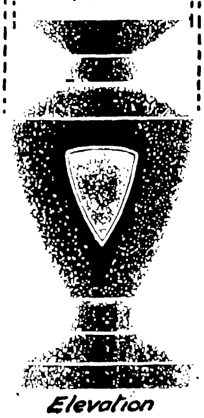


Fig. 11. Built-up square vase. For the making of a vase casting, see Fig. 2, p. 660.

VASES AND BOWLS

Vases and bowls may be made by casting, bossing or building up from cast or milled sheet, according to requirements. Moulds for castings may have the enrichments carved in or upon them, and are usually made in several parts to enable them to be separated after the casting has been made. Small articles may be cast as described under the heading Cast Lead Work. Large articles are often cast in several pieces and burnt together.

Built-Up Vase. For a built-up vase as shown in Figs. 11 and 12, cast or milled sheet can be used. The shape of each segment is first obtained by geometrical development (*see* Setting Out); it is then cut out, bent to the outline and the angles burnt together, the bottom being burnt on afterwards. If desired, each side may be cast separately (together with any ornament which may be needed) in the sand bed of a casting frame, afterwards being bent to shape and burnt together. If of milled lead, the ornament may be embossed in the lead before cutting out the shape of each side or segment; or they may be made separately and burnt or soldered on.

Fig. 12. Hexagonal vase built up of cast or milled sheet.

Bossing a Vase. The process to be followed when bossing a vase is similar to that described for the rainwater head shown in Figs. 1 to 3. A model in stone plaster or lead may be available from which to work, but a sketch will suffice. Ornamentation may be worked in the lead or made separately and burnt or soldered on. When bossing, care must be taken not to overwork the lead or it may become too thin—especially where the narrow stem is formed; it is better to

LEADWORK: ORNAMENTAL. Fig. 13. Bossed lead vase.

"gather" the lead at this point and thicken it to give strength for supporting the upper portion (Fig. 13). When working ornament on these jobs, chase wedges of soft wood are the best to use as they greatly assist movement of the lead without marking it or unduly thinning it. Like all other bossing operations, the work should be kept free from buckles and creases during the early stages.

Finials. Finials are used to give a finish to turrets and domes, and are employed also at intersections of hips and ridges. They may be of a simple or highly ornamental design, and the method of covering them varies according to their size and shape. A simple type is shown in Fig. 14. This, if small in size, can be covered in one piece of lead. If of a large size it should be covered in three pieces, the base A being put on first and fixed under the necking N. Sufficient lead should be allowed for weathering at the extreme bottom of base. The next piece B is then put on and worked under the necking N to lap the top of piece A, the top edge being fixed to the top of stem under the ball at M. The ball is then covered and the bottom worked in to lap the top edge of piece B. Figs. 15 to 17 show finials covered in one piece, that in Fig. 16 being the finish to an octagonal lead-covered turret. (*See* Finial.)

FLOWER BOXES

The early type of box was of wood and usually decorated externally with mouldings to form panels. Zinc linings were often provided, and the exterior was fitted with tiles of various shapes and colours.

Although very popular as window decoration during the last century and the early part of this, their popularity began to wane. They were often in need of repairs, as the moisture from the soil destroyed the wood or the zinc. A revival of their use has begun by forming them of lead. They may be built up to meet the requirements of various types of windows, either at sill level or over the windows of large business premises where a display of flowers is desired. Lead-lined wood boxes may be used with tiled exteriors if desired.

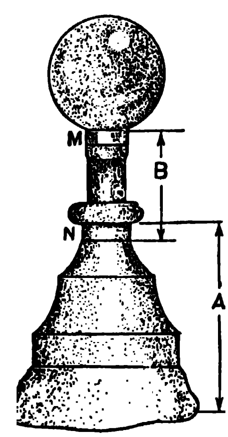
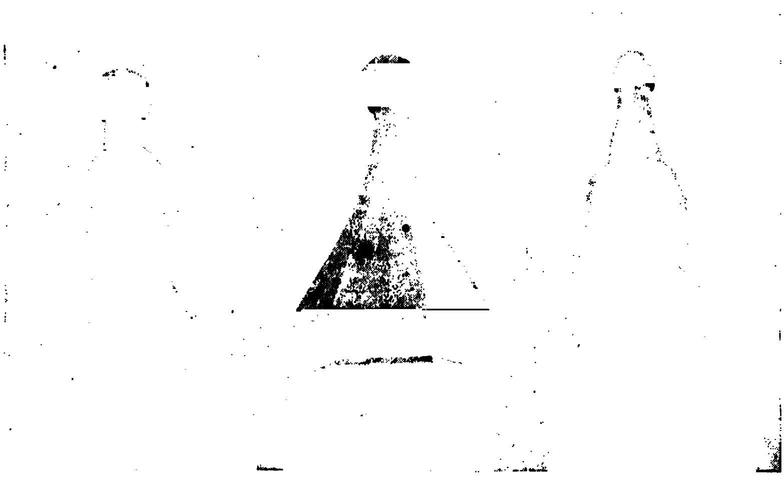
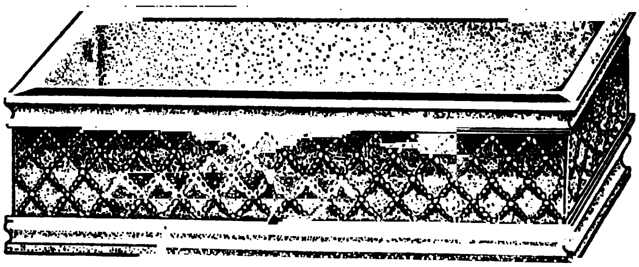


Fig. 14. Ball finial, covered in three pieces of lead. See text for details.

Boxes may also be made wholly of lead, but they need to be of good substance (not less than 8 lb. per foot super), and the angles should be soldered or burnt together. Milled or cast sheet can be used. If the former, moulding and ornament could be made separately and burnt on; in regard to ornament, much can be done by ordinary burning, shown on the front and end of the box illustrated by Fig. 18. This is a lattice pattern traced on the leadwork and formed by adding feed lead and fusing it to the lead box. A



Figs. 15–17. Finials covered in one piece of lead; overall heights—(15) 2 ft., (16) 2 ft. 4 in., (17) 3 ft. 9 in.



LEADWORK : ORNAMENTAL. Fig. 18. Small flower box of milled sheet lead decorated by burning lattice pattern, adding feed lead, and fusing it to box.

small lead pipe should be fitted to the bottom for draining purposes.

Boxes in Cast Lead. Cast boxes may be built up by using separate panels having mouldings and ornament cast on them as desired; these panels form the front or front and ends as the case may be, and are burned a cast lead base and back. If moulding and ornament are cast with the panel a great deal of fitting, preparation and burning are avoided. For large windows or shop fronts, boxes built up of cast sheet are to be preferred. For long spans they are made up in sections and burnt together in position. Internally they must be supported by cross stays fixed at intervals near the top edge. A very good form of stay is a length of copper tube passed through a length of stout lead pipe, both being flanged and burnt to the front and back of the box. This was the method used for window boxes on a London business house, shown in Fig. 19.

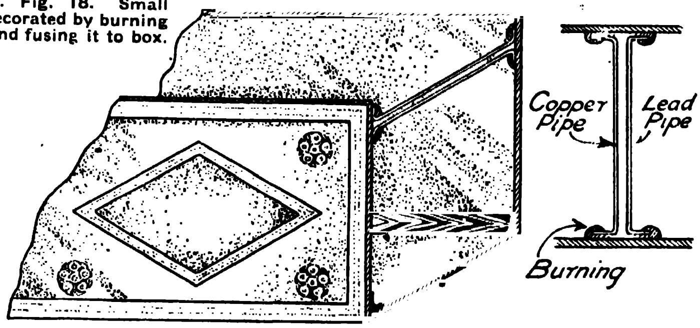


Fig. 19. Window-box in cast lead made of panels with cast-on ornament; supported by copper tube in lead pipe, both flanged and burned to front and back of box, as shown on right.

EMBOSSING

Embossed Work. An interesting and useful type of ornamental work is that of embossing in milled sheet lead. Many intricate or even simple but effective designs may be formed, and few tools are required for the purpose. A sketch of the pattern is usually sufficient guide, but a model of plaster or clay affords the worker a better idea of the depth necessary to give sufficient relief. The dolphin panel illustrated in Fig. 20 is embossed in 5 lb. lead, a printed illustration being used as a guide. This is an example of high relief. The small panels in Fig. 21 are of the same substance and are replicas of plaster casts. No mould or wood base is used, and the operations are carried out from the back as well as the front of the lead.

In embossing, much depends on the intricacy of the design as the best method to follow, but the following instructions will be a guide. The rough outline is chalked upon the lead, and outside this marking the lead can be worked down or gathered in from the edges so as to leave a well-raised portion untouched by the

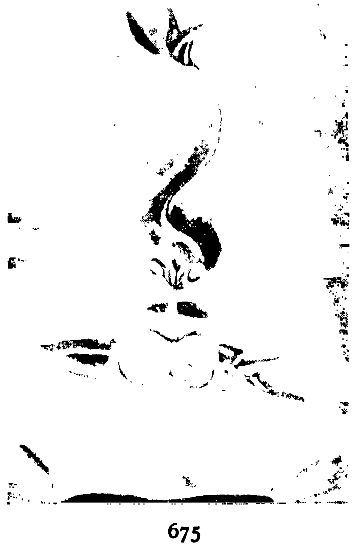


Fig. 20 (left). Bottle-nosed dolphin embossed in 5 lb. sheet lead. Fig. 21 (above). Ornamental embossed panels of 5 lb. lead, replicas of plaster casts.

bossing tools. In the next step much of the rough shaping can often be done with the mallet, and then by using blunt soft wood chase wedges. Where deep members are required the lead is best worked into the approximate position by forming gussets or folds and carefully driving them in with the face or side of the mallet. The finish is carried out with the soft wedges. If desired the outer edge of the lead can be formed into a moulding to make a complete panel after the ornamental design has been finished; or the designs can be cut out and burnt on to other surfaces. In order to give an added effect to these embossed panels, letters or monograms may be formed on the background by tinning. A coating of soil is applied, the letters marked out and cleaned with a shavehook, smeared with flux and a thin coating of pure tin floated over the surface. The soil may afterwards be washed off.

Curbs. Ornamental curb rolls and aprons are often used on a curb roof, and the rope pattern with bosses formed in the apron piece is a very effective design. The curb roll is carved to the pattern required and the lead worked into the members with the aid of chase wedges. The bosses on the apron can be worked into a wood mould on the bench. These coverings need to be securely fixed—best done by using stout sheet copper tacks or tingles at frequent intervals along the roof (Fig. 22).

Folding Plate. A number of photographic illustrations of typical ornamental leadwork are printed on the Plate facing page 672 (Figs. 23–37).

LEAKAGE FROM DRAINS. *See* Drains: (1) and (3).

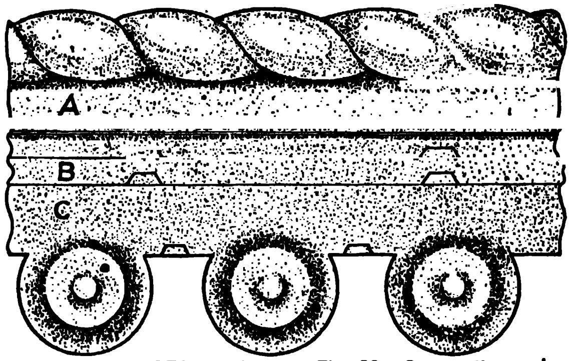
LIGHT AND AIR. It has long been recognized that new domestic buildings should have adequate open spaces in front of them as well as at the rear of them. Such provision for lighting and ventilation is regarded as essential to public health.

Outside the Metropolis. By-Laws 80 to 93 of Series IV of the Model By-Laws issued by the Ministry of Health deal with space about buildings and the ventilation of buildings. In general, outside the Metropolis the open space in front of a domestic building is extended to at least 24 ft. throughout its frontage measured at right angles to the building to the boundary of any land or premises immediately opposite; or, in the case of a building fronting a street, then to the opposite side of the street.

The open space at the rear is to be 150 ft. super, and the least distance from any projection of the building at the rear to the boundary of any land or premises immediately on the rear must be:

15 ft. if the height of the building is not more than 25 ft.
20 ft. if the height of the building is not more than 35 ft.
25 ft. if the height of the building is not more than 50 ft.

The open space required must extend



LEADWORK : ORNAMENTAL. Fig. 22. Curb roll covering and apron piece, secured to roof with stout sheet copper tacks: A, roll covering; B, moulding cover; C, apron.
For Figs. 23–37 see Plate f.p. 672.

throughout the entire width of the building, and if the accommodation for human habitation is wholly above the ground floor, the open space required is to be measured at the level of the lowest floor on which the accommodation for human habitation is provided.

A window (or windows) of every habitable room must have a total area of not less than one-tenth of the floor area of the room, and an area equal to one-twentieth the area of that floor area must be made to open. Such windows must not open into a court enclosed on every side unless the distance across the court—that is, the distance from the window to the opposite wall of the court—is equal to two-thirds the height as measured from the top of the window to the level of the eaves or tops of the parapet of the opposite wall. Nor must the window open into a court which is open on one side only if the length measured from the open side exceeds twice the width of the court, unless the window opens to the court or the side opposite to the open end, or unless the

distance across the court, measured as before, is equal to at least half the height measured as before described.

Inside the Metropolis. By Sect. 9 of the London Building Act, 1930, a street laid out for vehicular traffic must be at least 40 feet wide. When it is to be used for foot traffic only, it need be only 20 feet wide.

At the rear of a domestic building there must be provided an open space exclusively belonging to such building of at least 150 sq. ft., extending throughout the entire width of the building and to a depth of at least 10 ft. from the building. (Sect. 44.)

As to window area, provisions are made in the Act similar to those provided by the Model By-Laws (*see* p. 676).

Lighting Under Factories Act, 1937. The Regulations made 1941, require that the general illumination of the working part of a factory shall be not less than 6 foot candles at 3 ft. from the floor ; reduced to 2 foot candles if the source of general lighting must be fixed more than 25 ft. from the floor. Illumination of passage ways must not be less than half a foot candle. Local lights must be shaded to prevent glare, and reasonable precautions taken to prevent shadows causing eyestrain or risk of accident.

Windows and skylights to be kept clean on both surfaces, unless whitewashed.

Rights to Light and Air. No person has at common law a natural right of light to his land, but an easement of both light and air can be obtained by express grant, by implication of law, or by prescription under the Prescription Act 1832.

For all practical purposes the easements of light and air are similar.

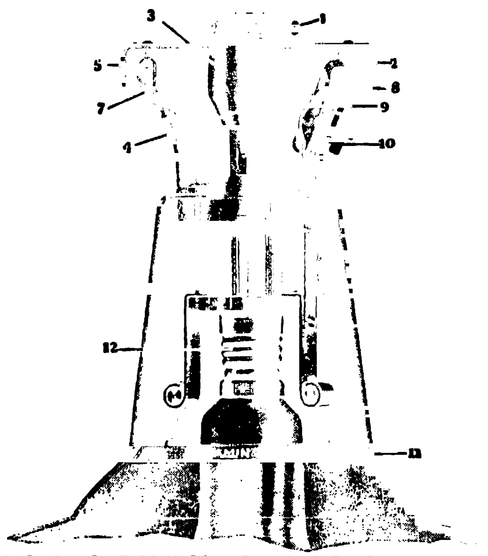
No one has a right to pollute the air which passes over his neighbours' land, unless he has acquired an easement to do so, and if he does so he is liable for a nuisance.

A person may acquire an easement in respect to his building for the free passage of air to it from his neighbours' land. So also can he acquire an easement for the continuance of light which has come to his windows. The amount of such light must be sufficient for the comfortable use and enjoyment of his building. If it is interfered with to such an extent to make his building uncomfortable, it is a nuisance. —*W. T. Creswell, K.C., Hon.A.R.I.B.A.*

LIGHTING FITTINGS : Electric. A well-planned lighting installation provides an even illumination on the working plane of adequate intensity for the purpose required, with, in general, a complete absence of glare and with sufficient directional effect to provide contrast (without which it would be impossible to appreciate the shapes of objects properly). It depends for its success partly on the choice of suitable lamp ratings and partly on the choice of fittings and their correct placing.

Fittings may be divided roughly into three classes—industrial, domestic and architectural. There is no strict line of demarcation between these various classes, which overlap to a considerable extent. Industrial fittings comprise mainly those designed for purely utilitarian purposes, with the object of making the most efficient and economical use of the light available. The old conical type of shade is still seen in service. It was designed for the now obsolete carbon filament lamp and is quite unsuitable for the modern electric lamp. Not only is it most inefficient but it does not eliminate glare. The modern industrial counterpart is the R.L.M. reflector ; the dispersive type is now regarded as almost standard for factory lighting. It has a cut-off of 20 deg., in accordance with Home Office recommendations, and the reflecting surface is of vitreous enamel, which ensures freedom from glare. For even illumination, the spacing should not exceed 1½ times the distance between the mounting height and the working plane. This type of reflector is available with 1⅛-in. hole attachment to standard lamp holders by means of a shade carrier ring up to 150 watts, and with a porcelain holder tapped for conductors up to 1,500 watts.

In some fittings the lamp caps in ratings above 200 watts become so hot that the cap cement fails to hold for the full life of the lamp, sometimes with disastrous results. This danger can be avoided by choosing fittings specially designed to keep the temperature of the cap and cables within safe limits, such as the " Coolicon " made by the General Electric Company and the " Saaflux " fittings designed by Benjamin Electric, Ltd. A further advantage of the latter type of fitting is that the reflector can be removed complete without disturbing the



LIGHTING FITTINGS. Fig. 1. " Saaflux " fitting: (1) grub screw; (2) earthing screw; (3) bakelite terminal; (4) contacts; (5) stirrup; (7) hook; (8) catch; (9) spring; (10) locking screw: (11) supplementary reflector; (12) lamp holder. (*Benjamin Electric Ltd.*)

wiring. When a large area has to be illuminated it is more economical to use a few lamps of high wattage than a larger number of low-wattage lamps.

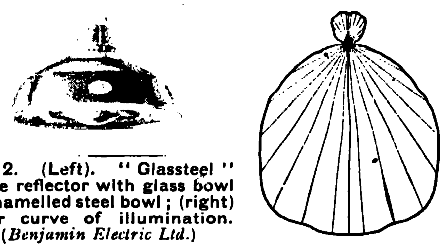


Fig. 2. (Left). " Glassteel " white reflector with glass bowl in enamelled steel bowl; (right) polar curve of illumination. (*Benjamin Electric Ltd.*)

A less severe effect is provided by the " glass-steel " type of reflector, which has a diffusing glass bowl within an enamelled steel bowl. This type may be provided with apertures in the top of the reflector to relieve the contrast between the lighting of the working plane and the ceiling. It is suitable for workshops, shops or offices. The spacing should not exceed $1\frac{1}{4}$ times the mounting height above the working plane. Where more light is required in one direction than in another (e.g. a narrow passage-way in stores) elliptical and elliptical-angle reflectors are available.

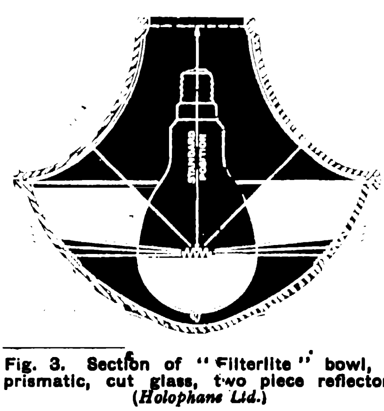


Fig. 3. Section of " Filterlite " bowl, prismatic, cut glass, two piece reflector. (*Holophane Ltd.*)

Concentrating reflectors are available for high mounting; in small wattages, these may also be used for local lighting by mounting close to the job.

Shop-window lighting is an art in itself: various special fittings are available, such as intensive and extensive window (or floodlights) and trough reflectors, supplemented by strip lights where necessary. Prismatic cut-glass reflectors to cover all of the above uses are available in the Holophane range (*see* Fig. 3).

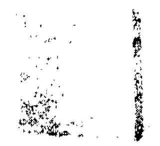


Fig. 4. Glass cube employed for lay-lighting or near-ceiling illumination. (*Benjamin Electric Ltd.*)

In the domestic range, for use in halls, bathrooms and kitchens, totally enclosed glass globes or cubes, either pendant or mounted flush with the ceiling, take a lot of beating for a clean, neat job.

The choice of fittings for living-rooms is largely a matter of individual taste and pocket, but it should be noted that many of the so-called " modern " fittings on the market are very inefficient and uneconomical.—*R. A. Baynton, A.M.I.E.E.*

LINEN CUPBOARD. A cupboard for the storing of clothes and provided with some means of keeping the air in the cupboard dry. The term is usually applied to comparatively small cupboards as distinct from large airing cupboards (*which see*). The linen cupboard must be provided with shelves formed from slats, providing spaces through which the air may circulate. It is necessary also that a certain amount of fresh air can gain access to the cupboard. The essential requisites are therefore a source of heat, means for air to enter and leave, and provision for circulation. Where guaranteed results or accurate results are necessary, the same principles should be followed as for airing cupboards (*which see*). Normally, a linen cupboard is dealt with by empirical methods.

Storage Vessel in Cupboard. For the usual small house it is probable that the linen

cupboard will be placed in or adjacent to the bathroom and almost vertically over the kitchen. If an independent boiler or back boiler is used for the hot-water supply system, the most convenient position for the storage vessel, whether it be cylinder or tank, will be at the bottom of the linen cupboard (Fig. 1). Here, if it is left uninsulated, more than sufficient warmth will be available for airing clothes. The part of the cupboard containing the storage vessel should have a door so that access may be gained to it: dust and dirt will collect, and the warm air convection currents will distribute this among the clothes. The storage vessel should have such dimensions, therefore, that it is possible to clean all round it.

LINEN CUPBOARD. Fig. 1. Copper hot water cylinder bottom of linen cupboard.

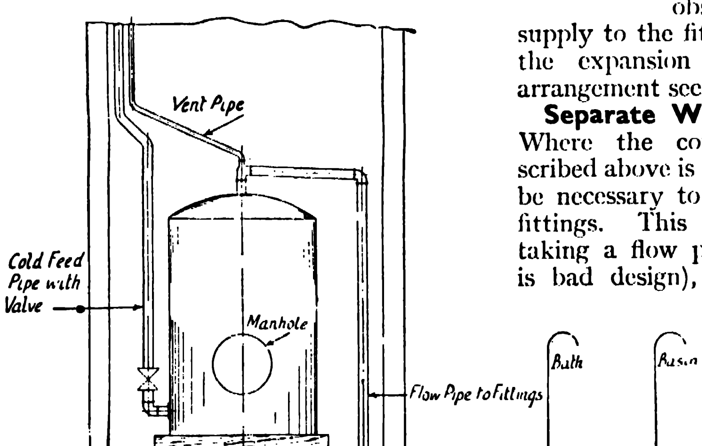


Fig. 2. Piping from tank or cylinder concealed in linen cupboard and arranged to occupy little space: tank on wood bearer, and having manhole facing door.

Where a comparatively expensive source of heat is used, little heat must be wasted. An uncovered cylinder or tank will give a temperature in the cupboard much higher than necessary for its linen store. This is immaterial when fuel costs are low, but when gas or electricity is used the storage vessel should be insulated, a minimum surface being left bare to warm the cupboard. The necessary area may be calculated by assuming the same emission for pipes which is given under Airing Cupboards. However, in the case of a small house it is sufficient to leave one or two sides of a tank bare, or the top third of a cylinder. The insulation should have a hard surface to protect it from knocks.

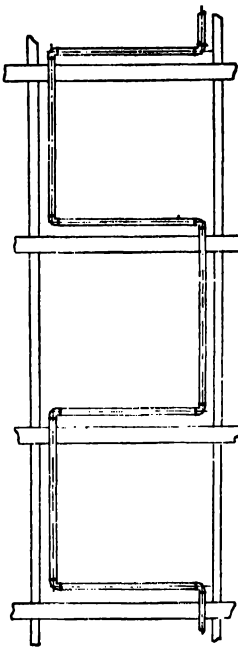
The tank or cylinder should be stood on wooden bearers to prevent condensation attacking its underside when the apparatus is not in use. If a manhole with cover is provided it should, of course, face the door. The linen cupboard forms a convenient concealment for the expansion and cold-feed pipes running to the roof. They should be set over to one corner to form as little obstruction as possible. The supply to the fittings may be taken from the expansion pipe, giving the neat arrangement seen in Fig. 2.

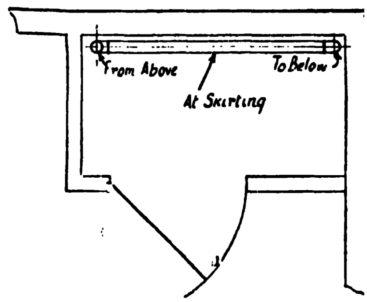
Separate Warming Arrangements. Where the compact arrangement described above is impossible it will probably be necessary to run a circulation to the fittings. This cannot be done without taking a flow pipe into the roof (which is bad design), with cylinder and taps on the same level. In such cases, therefore, the cylinder should not be fixed in the linen cupboard, and special provision should be made for warming the latter. This will also apply to large houses and larger buildings generally.

The usual and best method is to provide a pipe coil at the bottom of the cupboard, fed with hot water from the nearest circulation. A double-pipe coil of $1\frac{1}{4}$ in. pipe for cupboards of small depth, and 2-in. pipe for those of large depth, will be

Sink

quite adequate. It should be run round at least two and preferably three sides of the cupboard. If one side only can be used, or if the cupboard is deeper than its width, a three- or four-pipe coil is preferable. Precautions regarding venting and control of the coil should be taken as described under Airing Cupboard (*which see*). The lowest shelf should be at least 9 in. above the top of the coil. When electricity is the heating medium, long circulations should be avoided as causing waste. Tubular heaters are then to be preferred, arranged similarly to the pipe coils. Linen must not come in contact with heaters, and a free space must be allowed round them. If clothes are placed directly on them, so that heat radiation is prevented, they will overheat, probably burn out, and may even set the clothes on fire.





LINEN CUPBOARD. Fig. 3. Cupboards in block of flats, warmed by single drop pipe : (left) pipe enters at top of one cupboard, crosses at skirting level, and drops through to next cupboard (see text) ; (above) plan of one cupboard, showing pipe across cupboard at skirting level.

Cupboards in Blocks of Flats. Here simpler methods of warming are often possible. Cupboards are often one over the other. Here a pair of risers may be run straight up through them and will provide sufficient heat. If the bathrooms adjoin the cupboards the risers should be on the side remote from the bathrooms. The pipes running into these rooms should be at skirting level in the cupboards, so providing additional heat. If the drop system is used, a drop pipe may be taken in at one side of the top cupboard, cross at skirting level and drop through to the next cupboard. Here it should be taken down to the skirting, cross again to its original side and so down to the next cupboard (Fig. 3.) The arrangement is economical, but the heat cannot be controlled.—*L. C. C. Rayner, A.I.E.C.*

LOCAL AUTHORITIES: POWERS OF SANITARY ADMINISTRATION

By W. T. Creswell, K.C., Vice-Pres., R.San.I.

Here the position of the various Authorities is explained as regards Sanitary Administration, both inside the Metropolis and outside. A summary is given of the principal sections of the Public Health Act, 1936, which concern sanitary matters and water supply. *See also* Entry, Powers of ; London County Council By-Laws ; Model By-Laws ; and other articles referred to in text.

Powers to carry out sanitary administration outside London in connexion with various Acts of Parliament is given to county councils, county borough councils and county district councils—that is, non-county borough councils and urban and rural district councils. Similar powers are also given to port health authorities. As far as London is concerned, powers are given to the Common Council of the City of London, the London County Council and metropolitan borough councils. In London, most of the sanitary law is contained in the Public Health (London) Act, 1936 (*see* details below) and London County Council General Powers Acts though, as is pointed out elsewhere (*see* Drains and Drainage: 2), Drainage By-Laws as regards London have been made under the Metropolis Management Act of 1855 and the amending Act of 1899.

A. WITHOUT THE METROPOLIS

Sanitary law is in the main contained in the Public Health Act of 1936, Section 1 of which defines the sanitary authorities for the purposes of that Act. The Act also

gives power to the Minister of Local Government and Planning to constitute a Port Health Authority or Joint Boards to carry out certain sanitary duties, the powers of these authorities being laid down by the Act. (*See* Public Health Acts.)

Local authorities for the purpose of the Act of 1936 are those mentioned in the beginning of this article, and hence become sanitary authorities under the Act. The following enactments also contain sanitary provisions and also provide for their enforcement by the authorities named in the Act :

Factories Act, 1937. Under this Act, councils of county boroughs, boroughs and urban and rural district councils are the authorities for the carrying out of certain of the provisions of the Act relating to workshops, factories and workplaces (including offices). (For the contents of the Act, *see* Factories Act.)

Housing Act, 1936. County councils, councils of county boroughs, boroughs and urban and rural district councils are the local authorities for sanitary administration under this Act. (*See* Housing Acts.)

Shops Acts, 1912–1936. The enforcement of the sanitary provisions of the Shops Act, 1934, relating to sanitary conveniences is the "Sanitary Authority," defined by Section 15 of the Act as the council of a county borough or county district and, as respects London, the enforcement of these provisions is in the hands of the sanitary authorities under the Public Health (London) Act, 1936. (*See* Shops Acts.)

Rivers Pollution Prevention Acts, 1876 and 1893. Local authorities, as sanitary authorities, are responsible for the enforcement of provisions of this Act.

Public Health (Drainage of Trade Premises) Act, 1937. Gives local authorities some control over the passing of trade effluent into sewers.

Generally. The Ministry of Local Government and Planning is empowered to carry out and co-ordinate general measures conducive to the health of the people ; and hence it functions in close collaboration with sanitary authorities, both the Minister and the authorities themselves obtaining their authority from various Statutes. This close connexion is illustrated particularly by the powers given to the Ministry to confirm by-laws made by an authority under a particular Act, as well as by the formulating of Model By-Laws dealing with a particular subject. Furthermore, by Section 318, the Minister is empowered to cause local inquiries to be held where differences arise in the administration of matters, sanitary and otherwise, and to take action in cases of default by local authorities in regard to their statutory duties. It may also be provided that appeals can be made to the Minister where action is to be taken by a local authority, or where disputes arise between an authority and persons concerned. Thus, under the Public Health Act, 1936, appeals can be made to the Minister as regards sanitary matters.

Public Health Act, 1936 ***(Outside the Metropolis)***. The principal powers of local authorities as regards sanitary administration under this Act are as follows (numbers refer to Sections) :

17. Adoption of sewer or drain, or sewage disposal works, at a future date.

19. Require proposed sewer or drain to be so constructed as to form part of general system.

22. Alteration and closing of public sewers.

24. Recovery of cost of maintaining certain lengths of public sewers.

29. Land held for treating sewage : management of, or leasing.

42. Alteration of drainage system of premises.

43. Rejection of plans of new buildings without sufficient and satisfactory closet accommodation.

44. Provision of closet accommodation where existing is insufficient and unsatisfactory.

45. Compulsion of owner to repair defective closets.

47. Replacement of earth closets, etc., by water closets at joint expense of owner and local authority.

48. Examination and testing of drains believed to be defective.

61. By-laws as to buildings and sanitation. (*See* Model By-Laws.)

63. Relaxing of requirements of by-laws, with consent of the Minister.

65. Removal or alteration of work not in conformity with by-laws, etc.

67. Reference of questions arising under building by-laws to the Minister.

74. Cleansing of cesspools on behalf of owner or occupier.

87. Provision of public conveniences.

88. Control over conveniences in, or accessible from, streets.

89. Provision of sanitary conveniences at inns, refreshment-houses, etc.

Water Supply

112. Power to supply water for non-domestic purposes, arising out of their duty in respect to water supplies in their district.

114. Supply of water in bulk to adjoining authority.

116. General powers of supply.

125. Utilizing of wells, springs or streams by parish council.
138. Sufficient water supply to occupied houses.
140. Closing, or restricting use of water from, polluted source of supply.
260. Power of parish council or local authority with regard to ponds and ditches.

Water Act, 1945. Section 17. By-laws for the prevention of waste, undue consumption, misuse or contamination of water. (*See* Model By-laws, Series XXI).

General Provisions as to Powers of Local Authorities. By Section 272 of the Act of 1936, any two or more councils may, by agreement, combine for the purposes of any of their functions under the Act and, by Section 275, can execute certain drainage etc. works on behalf of the owners or occupiers.

Sanitary Inspection. The appointment of sanitary inspectors of boroughs, urban and rural district councils to discharge the duties of local authorities under the Act is provided for under Sections 106 and 107 of the Local Government Act, 1933.

B. WITHIN THE METROPOLIS

Sanitary authorities in London, are the Common Council of the City of London, the London County Council, and metropolitan borough councils, and, under the Public Health (London) Act, 1936, Section 9, every sanitary authority must appoint an adequate number of sanitary inspectors.

The principal duties of sanitary authorities under the Public Health (London) Act, 1936, are (nos. refer to Sections):

15. Power of County Council to take over sewers not vested in them.
18. Alteration or discontinuance of sewers by borough councils.
27. Approval of new sewers by County Council.
33. Directions to borough councils in regard to sewerage.
38. Borough council to compel owner to construct drains into sewer.
44. Construction or alteration of drains by agreement with borough council.
46. Supervision by County Council of sewers made by borough councils (for connexions, *see* Sections 47, 48, 49).
107. Making of by-laws as to sanitary conveniences. (*See* London County Council By-laws.)

LONDON BUILDINGS ACTS. *See* Acts and By-laws.

LONDON COUNTY COUNCIL BY-LAWS: SANITATION

By W. T. Creswell, K.C., Vice-Pres.R.San.I.

In various articles throughout this work the By-law requirements are noted in respect of the particular subject under discussion, but here a complete review in brief is given of the L.C.C. By-laws which concern the Plumber and Sanitary Engineer. See *also* Drains: (2); Flats; Traps; Water Closet.

Drainage By-laws have been made under Section 202, Metropolis Management Act, 1855, and the Metropolis Management Acts Amendment (By-Laws) Act, 1899.

Subsoil Drains. A subsoil drain—that is, a drain used solely for conveying to a sewer water that may percolate through the subsoil—must not be connected directly with a sewage drain, or sewer, or a surface water drain, without a suitable trap. The trap must have near it a ventilated opening communicating directly with the open air.

The subsoil drain must discharge into the trap and be formed of earthenware, field or other suitable pipes laid to an adequate fall (By-laws 1 and 2). (*See* Drains: (2) for details of construction of traps, etc.)

Surface Water Drains. These drains are those which convey to a sewer rainwater from roofs or from ground surfaces, whether paved or unpaved. They do not include rainwater pipes, and they are not necessarily required to be of 4 in. diameter. But when such a drain is intercepted from a sewage drain or sewer by a suitable trap communicating directly with the open air, and with adequate means of access, then, if the inlet to such drain is not less than 10 ft. distant from any building, the inlet may be an untrapped gully made so as effectively to catch sand or other detritus, and covered with a grating, the bars of which are not to be more than ⅜ in. apart. When such drain receives only rainwater from roofs its inlet may be by a rainwater shoe or an untrapped gully, as before described (By-laws 1 and 3). (*See* Drains: (2) for details of construction, materials, etc.)

Rainwater Pipes. These are pipes or drains situated wholly above ground, and used, or constructed to be used, solely for carrying off rainwater directly

from roof surfaces. They must discharge directly, or by means of the channel, into or over an inlet to a surface water drain, or to the sewage drain. A sewage drain is a drain used or constructed to be used for conveying solid or liquid waste matters to the sewer. When the inlet to a drain is a properly trapped gully, or other suitable trap, the pipe or channel above referred to must discharge above the level of the water in such gully or trap.

A rainwater pipe is not to discharge into or connect with any soil pipe or soil ventilating pipe (By-laws 1 and 4).

Sewage Drains. A sewage drain can be constructed of cast-iron, glazed stoneware or other suitable material. If the pipes, traps and fittings are of cast-iron, they must be protected against corrosion both inside and outside, as by a coating of Dr. Angus Smith's solution or the like. Their thickness, traps and fittings, weight of pipes and depths of sockets and caulking space must comply with Table No. 1 of the schedule of the by-laws (*see* Table II, Drain Pipes: (2) Cast Iron). If they are constructed of stoneware, they must be of first quality, properly glazed, and their thickness, etc., must comply with Table No. 2 of the schedule (*see* Table I, Drain Pipes: (1) Stoneware).

Every drain must be of a suitable size and at least 4 in. in diameter, laid with a suitable fall and, if possible, in a direct line. The joints of cast-iron socketed pipes are to be made with a gasket of hemp or yarn and metallic lead, properly caulked. Cast-iron flanged pipes are to be securely bolted together with some suitable insertion. Stoneware pipes, or pipes of material other than metal, are to be jointed with socket joints, with a gasket of hemp or yarn and cement, or the like.

Stoneware drain pipes are to be laid in a bed of concrete 6 in. thick, projecting each side of the drain not less than 6 in. Concrete is to be filled in the full width of the bed and haunched up to not less than half the diameter of the pipe. If the drain is constructed of cast-iron pipes above the ground, each joint of it may be carried on adequate piers or other supports.

Branch drains must join another drain obliquely in the direction of its flow. If a drain is laid under a building, it must be laid in a direct line, if possible, and with means of access to it. When made of stoneware pipes, it must not only be laid on the bed previously described but must be encased in concrete at least 6 in. thick. If of cast-iron pipes, it must be laid on a similar bed of concrete and filled in and haunched up with concrete only. A drain laid beneath a wall must have a relieving arch or other support to the wall over.

There must not be any inlet to a drain within a building, except one to a soil fitment, or a waste water fitment connected directly to such drains. All inlets to drains are to be trapped, and all trapped gullies are to have gratings.

If an intercepting trap is provided (the provision of which a Sanitary Authority can enforce) it must be placed as near as practicable to its connexion with the sewer, and provided with a manhole (that is, a disconnecting manhole) or other means of access. The water seal in the trap is to be 2 in. deep, and the trap is to be fitted with a raking or clearing arm, fitted with a secure stopper.

A drain is to be watertight and capable of resisting a pressure of 5 ft. head of water. If an intercepting trap is provided to it, then it must have at least two ventilating pipes. When there is no intercepting trap, only one ventilating pipe need be provided. The ventilating pipe is to be at least 3 in. in diameter, and soil and waste pipes and ventilating pipes may be used as drain ventilating pipes. Every ventilating pipe must have a grating at its open end (By-law 5).

Soil pipes and soil ventilating pipes may be of lead, copper, cast-iron, wrought iron or the like: they must not be connected with any rainwater pipe, or with any waste pipe, or waste ventilating pipe, unless it be constructed in accordance with the by-laws. There can be no traps in these pipes and they must be watertight and resist a pressure of 5 ft. head of water. Provision is made in the by-laws for the method of jointing the various kinds of soil pipes, traps, etc., with drains (By-laws 6 and 7).

Slop Sinks and Urinals. A slop sink is a sink constructed or adapted to be used for receiving solid or liquid excremental matter; and a slop fitment is a water closet, slop sink, or a urinal.

A slop sink is to be of glazed earthenware, enamelled fireclay or the like material with a flushing rim, water supply, and apparatus for flushing both the sink

and trap and waste pipe therefrom. They must be trapped immediately beneath and be provided with means of inspection and clearing.

When two or more urinal basins or stalls are fixed in a range, the waste pipes may discharge without a trap, into a channel beneath, fixed in or on the floor, the channel itself discharging into a suitable trap (By-law 8).

Generally traps must be ventilated by a trap ventilating pipe taken into the open air (By-law 9). A waste water pipe must have an internal diameter of at least 1½ in., and must be constructed of lead, copper, cast-iron, wrought iron, glazed stoneware or other suitable material. Also it must be trapped. (By-law 10.) No pipe, trap, apparatus, etc. can be marked " L.C.C. " or " London County Council " unless it conforms to the by-laws. (By-law 11.)

The owner of a house or building must maintain in a proper state all drainage work, and no alteration or repair can be made unless it complies with the by-laws. (By-laws 12 and 13). Plans, sections and block plans and notices of drainage work must be deposited with the sanitary authority concerned seven days before beginning the work. (By-law 14.)

Water closets, Urinals, etc. By-laws made by the L.C.C. in 1930 require that one side of a water closet shall be an external wall, and if the surface of its floor is at, or above or not more than 5 ft. below the ground level, such external wall must abut immediately upon (1) a street, the surface of which must not be more than 5 ft. above the level of its floor; or (2) an open space dedicated to the public or permanently secured to the building, and having a surface area of at least 100 sq. ft., at a level not exceeding 5 ft. above the floor of the water closet. The minimum width of the area is to be 3 ft. if enclosed on two sides, and 7 ft. if enclosed on every side.

When the surface of the floor is more than 5 ft. below the ground level, the external wall must abut upon an area or open space not covered in otherwise than by a suitable grating, and at least 40 ft. square and 5 ft. wide. If such space is for lighting and ventilating the water closet only, it must be at least 5 ft. by 5 ft. measured horizontally. The area or space last referred to must abut upon, and its surface is not to be more than 12 feet below, a street, or forecourt immediately adjoining a street, or an open space as referred to in (2) above.

If the water closet does not exceed 20 ft. in height, or the height of the storey in which it is situated, it may be so situated as not to have any external wall at all, that is to say, if a street or an open space, as previously referred to, is available at the level of, and abutting on, the roof of the water closet; and again, the water closet may be so situated that none of its sides is an external wall, and without any such open space, if means of artificial lighting and a system of mechanical ventilation are provided to it.

A water closet must not be situated within, or entered from any room used for human habitation, or as a scullery, schoolroom, office, factory, workshop, workplace, or for the manufacture, preparation, storage, or sale of food or drink for man, or as a public room, except through the external air or an intervening entrance lobby. But a water closet used exclusively with a bedroom or dressing room may be entered directly from such room.

Lighting and Ventilating. If a water-closet contains a single soil pan or basin, and an external wall is provided to it, it need only have a window in the external wall 2 square ft. (exclusive of its frame) half of which must open. In addition an air-brick, air-shaft, or other means of constant ventilation must be provided.

If such water closet has two or more soil pans or basins, then the window or windows in the external wall must be equal to one-fifth the floor space, and one or more air-bricks, air-shafts, or other suitable means of constant ventilation must be provided, having a total unobstructed sectional area of not less than 20 sq. in. per soil pan or basin.

If the water closet has no external wall, but is provided with the open space already referred to, then it must have a glazed lantern light or skylight, of an area of not less than one-fifth the floor, space and having in it louvred or other suitable openings equal to one-tenth of the floor space. The air shafts must be provided as before described. If the water closet is under a public footway, pavement lights may be used and suitable

inlet and outlet air-shafts must then be provided, the outlet shaft being fitted with a suitable exhaust fan.

If the water closet has no external wall, and no open space, it must have mechanical ventilation separate from any system of ventilation installed for any other purpose ; with a sufficient number of fresh air inlets, and a fan and motor or other mechanical means (in duplicate) capable of extracting air from the water closet at a minimum rate of 750 cu. ft. per hour per soil pan or basin. The aerial content must be changed three times per hour.

Soil Pan or Basin. This must be constructed of glazed earthenware, enamelled fireclay, or other equally suitable material, fitted with a flushing rim and of such shape, capacity and made of such construction as to receive and contain sufficient water to cover filth deposited in it, and to allow such filth falling free of its sides and directly into the water in the pan or basin. Its trap must have a proper water seal and be of lead, copper, cast-iron, glazed earthenware, enamelled fireclay or the like ; with an exposed and accessible outgo or outlet for connecting to a soil-pipe or drain. The trap must be fixed immediately beneath the soil pan or basin, which must be furnished with suitable seat rims or insets, or a hinged seat.

Flushing Cistern and Apparatus. This must be separate and distinct from any cistern used for drinking water, and must give a discharge or flush of not less than 2 gallons of water. There must not be any direct communication between any water service pipe and any part of a soil pan or basin. The number of water closets required in a building is one to every twelve inmates. All alterations or repairs made to a water closet must comply with the by-laws.

Urinals. For all practical purposes a urinal is regarded as a water closet ; therefore its situation, entrance lobby, construction, lighting and ventilation follow that for water closets already described. The fan and motor or other mechanical means of extracting air from the urinal must extract it at a minimum rate of 750 cu. ft. per hour per urinal basin, or each width or length not exceeding 2 ft. 3 in. of stall or trough respectively ; and the aerial contents of the urinal must be changed at least three times per hour. A urinal must have a basin, stall or trough of glazed stoneware, glazed earthenware, enamelled fireclay or the like, and of such shape as to ensure cleanliness. It must have a suitable flushing cistern, separate and distinct from any cistern used for drinking water, with a flushing capacity of at least 1 gallon of water for each connected basin, or each width or length not exceeding 2 ft. 3 in. of stall or trough respectively. This flush must discharge once in a period not exceeding 25 minutes, and the flushing cistern must be automatic and connected to the urinal basin with a flush pipe of at least ½ in. internal diameter fitted with a suitable spreader or sparge pipe, so as to distribute the water over the internal surface of every basin, stall or trough.

There must be no direct connexion between any water service pipe upon the premises and any part of a urinal basin, stall or trough. All alterations, repairs of any water closets, etc. must be done in conformity with the by-laws.

Regulations for Places of Public Entertainment. These were made by the London County Council in 1939 with respect to requirements for the protection from fire of places of public entertainment within the Administrative County of London, but regulation No. 38 deals with sanitary provisions, and a scale on which watercloset and urinal accommodation is to be provided is given.

Water Closets. Males, one for 200, 2 between 200-500, 3 for 500-1,000, and an additional one for every 500 (or part) over 1,000. Females, 1 for 100, 2 between 100-250, 3 for 250-500, and an additional one for every 400 (or part) over 500.

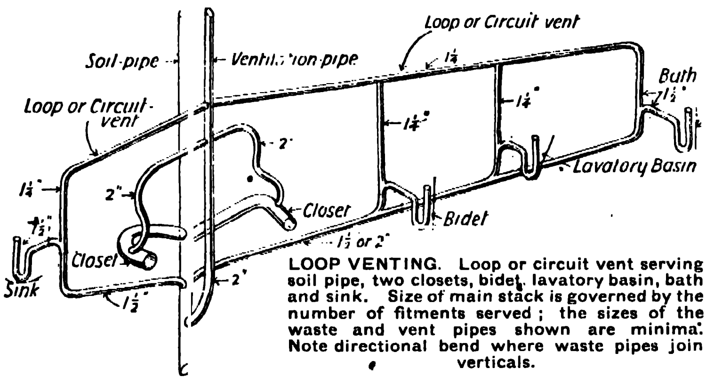
Urinals for Theatres and Music Halls : one for each 50 males. For dance halls, restaurants, etc. : one for each 100 males. The Council may also require separate accommodation for the staff, performers and orchestra. Urinal stalls must be automatically flushed, constructed in accordance with the by-laws, sloped to a drain, and must not, except where unavoidable, be approached from the auditorium or from spaces where the public are awaiting admission.

Notice of Work. 24 hours' notice in writing is required by the sanitary authority concerned, of any work to be done falling within these by-laws. (By-law 9.)

LOOP VENTING. The term " Loop Venting " finds no place in English legis-

lation governing plumbing or drainage work, but is recognized in the trade to mean that a loop or circuit is formed by a branch waste and vent pipe from the main soil or waste pipe to the main ventilation pipe, into which the trapped wastes, together with the ventilation pipes from the various sanitary fitments are connected, as shown in the diagram.

The particular arrangement of loop or circuit ventilation became popular with the advent of the "One-pipe" system of plumbing, which provides for the reception of discharges of bathroom fitments (*i.e.* bath, lavatory basin and bidet), and possibly an adjacent kitchen sink or bedroom lavatory basin, into the one loop or circuit. It is good practice to install vertical pipes within the loop and connect trap and waste from fitment to such pipe, providing the crown of trap is not nearer than 3 in. and more than 12 in. from point of connexion, which is a by-law requirement. The lower part of the vertical pipe forms the waste, while the upper portion, which joins the loop, provides ventilation. The connexion of trap-vent or anti-siphon pipes to the main vent stack should be at a point well above the top of the highest fitting connected to the stack.



LOOP VENTING. Loop or circuit vent serving soil pipe, two closets, bidet, lavatory basin, bath and sink. Size of main stack is governed by the number of fitments served; the sizes of the waste and vent pipes shown are minima. Note directional bend where waste pipes join verticals.

Invariably the closet fitment is connected direct to the vertical combined soil and waste pipe; but it can, if desired, be connected to the loop, which necessitates a larger size pipe up to its point of connexion than is necessary when installing a loop to take only washing fitments.

The system of loop or circuit ventilation is now generally adopted in the sanitary construction of residential flats, seeing that the sanitary fitments are situated above each other on succeeding floors, and one loop will serve as waste and vent pipe for each group of fitments on each floor. (*See* Flats; One-Pipe System.)

American Practice. The term "Circuit and Loop Vents" as applied to plumbing work is used, from a legal standpoint, in the Plumbing Code recommended by the Committee set up by the U.S. Department of Commerce and practised in America. Section 106 of the Code states that:

"A circuit or loop vent will be permitted as follows: A branch soil or waste pipe to which two, and not more than eight, water-closets, pedestal urinals, trap standard slop sinks or shower stalls are connected in the series, may be vented by a circuit or loop vent, which shall be taken off in front of the last fixture connexion. Where fixtures discharge above such branch, each branch shall be provided with a relief one-half the diameter of the soil or waste stack, taken off in front of the first fixture connexion."

It will be noted that a number of fitments, not exceeding eight, can be connected to a branch waste pipe which continues upwards independently, or forms a loop with the main ventilating pipe, without installing a separate vent pipe to the trap of each fitment. This arrangement is not permissible under English regulations, particularly as further concessions are granted such as that the trap can be 5 feet away from the vent (Section 101), and the 2-in. permissible trap seal is allowed to lose not more than 1 in. due to siphonage influences.—*F. C. Cook, M.R.San.I.*

LOW PRESSURE SYSTEM (Acetylene). *See* Acetylene.

LOW TEMPERATURE HEATING. *See* Radiant Heating.

MALLEABLE IRON. A form of white iron which after casting is rendered ductile by an annealing process. *See* Iron.

MANDREL. A cylindrical piece of timber used for trueing up the bore of large diameter lead waste and soil pipes. Mandrels may be obtained in diameters from one inch upwards, and the length varies from 12 in. on the driving mandrel to 30 in. or 36 in. on the bending mandrel.

They may be obtained in different types of timber, depending on the price paid, the best being of Turkey boxwood or beech.

The short driving mandrel may be employed in a similar manner to the bobbin, for taking kinks and distortions out of the pipe. The bending mandrel is placed in the ends of short lengths of pipe to give added leverage for the "pull round" to form the bend; or is pushed in the bore of the pipe to enable it to be dressed back to shape after it has become flattened by working with the dummy. A useful tip is to grease the mandrel well when new, and periodically afterwards ; this will make it easier to push in or withdraw from pipe.

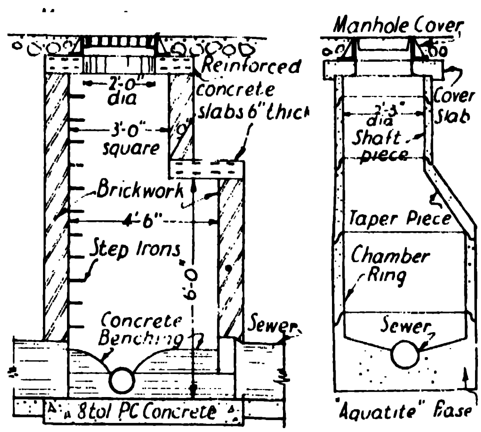
MANHOLE : Brick or Concrete. Manholes or inspection chambers are constructed on drainage systems to provide means of access for inspection and testing and for clearing in case of stoppage or obstruction. A manhole should be provided at the point of interception, or disconnexion, between the drain and the sewer, and also at the principal junctions of branch drains, and at changes of direction in the line of drain.

The size of a manhole depends on its depth, size of the main drain and number of branches that enter it, taking into consideration in all instances that it is a means of access, and that a man may have to enter and work in it, apart from the manipulation of drain rods. Suitable sizes for shallow manholes roddable and accessible from ground level are from 1′ 6″ × 2′ 0″ to 1′ 9″ × 2′ 3″. For deep manholes, from 2′ 0″ × 3′ 0″. Turning manholes, or manholes in which a change of direction in the line of the drain takes place, may be constructed from 18″ × 18″, according to depth and circumstances.

Deep manholes (say 6′ 0″ and over), of extended length on account of the number of branch drains entering, may be reduced in size at a suitable working height (say 5′ 0″ from the channels) by turning over an arch, and be carried up therefrom at a size of 2′ 0″ × 2′ 0″, or 1′ 6″ × 2′ 0″. They should have an iron ladder, or galvanized step irons at 12″ centres.

A brick-built manhole should be on a 6-in. concrete base projecting not less than 3 in. outside the walls. Provide proper footings to the walls, and construct brickwork in cement mortar. For manholes not in glazed brickwork, inner surfaces should be rendered with cement and sand so as to be watertight. Manholes constructed for access to a cast-iron inspection chamber, or with any other type of bolted cover at channel level, need not be constructed so as to be watertight above the bolted cover.

Channels. A half-section glazed main channel is fixed in the base of, and for the whole length of, the manhole, and connected to the drain at each end. Benchings of fine concrete should be formed, and

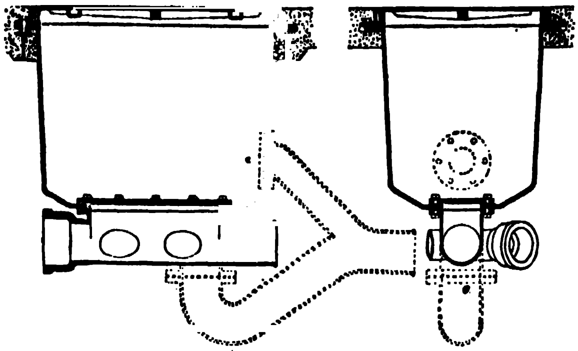


MANHOLE : BRICK OR CONCRETE. Fig. 1 (left). Section through deep brick manhole. Fig. 2 (right). Section through "Aquatite" pre-cast concrete manhole. (*Sharp, Jones & Co., Ltd.*)

benched up from the edge of the channel to the sides of the manholes. Branch drains should be connected to manholes by means of three-quarter section channels, bedded in fine concrete and connected to the main channel so that the discharge from the branch drain is in the direction of flow. Concrete benchings should be continued up from the branch channels in the same manner as for main channels.

Cover. The manhole should be provided at ground level with a suitable cast-iron cover having a deep grease seal, and of a type compatible with the class of traffic that is likely to pass over it. (*See* Manhole : Cast Iron.) For special surfaces at ground level, a recessed cover can be used, and be filled in with the same material as the floor construction.

Access Chambers. Except for the omission of glazed channels, brick or concrete manholes for access to cast-iron inspection chambers on a line of cast-iron drain should be constructed in the same manner as described above, the brickwork being pointed instead of being rendered.—*W. J. Woolgar, M.R.San.I. See* Inspection Chamber ; Intercepting Chamber.



MANHOLE : CAST-IRON. Sections through cast-iron manhole showing flanged top, inspection chamber with cover inside manhole, and positions of branches.
Burn Bros., Ltd.

MANHOLE : Cast-Iron. Where it is essential that access to a suspended drain be given from the floor over, a cast-iron manhole (*see* above diagram) is used, the size approximating to that of a brick manhole which would be built around a similar inspection chamber at a like depth.

On Suspended Drains. The top of the cast-iron manhole is flanged to receive an ordinary surface cover frame, the bottom of the manhole being similar to a standard cast-iron inspection chamber, on the cover flange of which rests the manhole base flange. The inspection chamber cover rests upon the base flange and is within the manhole.

The whole is bolted together with ⅝-in. manganese bronze bolts and gunmetal nuts, greased felt washers being used between the flanges as for inspection chambers.

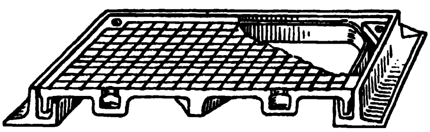
The body of the manhole is usually of ½-in. metal, which is found to be strong enough for shallow manholes; deep manholes require a greater thickness, which depends upon size and position. The flanges are usually machined, as extreme accuracy is essential.

The body of the manhole must be large enough to afford easy access, since it may be necessary for a man to enter. If the manhole is of considerable depth the body is made in sections, each being flanged and bolted to the lower member. The top of a deep manhole may taper so that the manhole cover may be of reasonable size (say 2′ × 1′ 6″ or 2′ × 2′). Cast-iron manholes have been made as deep as 9 ft., in 3 or 4 sections and with step irons bolted to the body to facilitate ingress and egress.

Interceptors. An interceptor may be applied to the manhole by means of a bottom outlet to the inspection chamber, to which a trap and flanged clearing arm are fixed. The latter is brought to the body of the manhole, to which it is bolted. Access is obtained from within by removing the bolted blank flange.

Where for suspended drains access must be given at the floor over, it is frequently found more desirable to construct a light reinforced concrete manhole with the standard inspection chamber in the bottom and a selected manhole cover and frame at the top.

Manholes in the Ground. Cast-iron manholes may be used in the ground as well as for suspended drains, particularly where brickwork or concrete construction is difficult because of water-logged or moving soils. Generally, however, the use of cast-iron manholes should be avoided. They are very costly, and when of large size extremely difficult to handle; the greatest possible care must be taken when ordering, as the manholes are good for one position only. Though considered indispensable by some authorities for certain conditions, the cast-iron manhole is not generally desirable, and other means should be examined before its use is decided upon.



MANHOLE COVER. Fig. 1. Stamford " cover and frame, fixed outside seal.

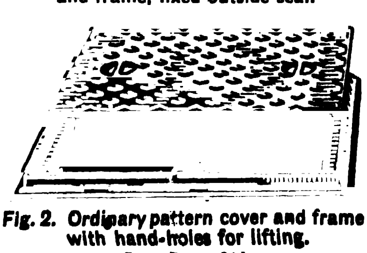
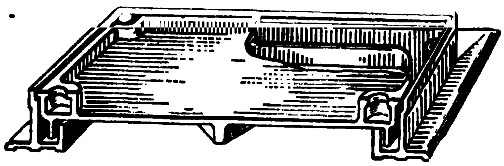


Fig. 2. Ordinary pattern cover and frame with hand-holes for lifting.
Burn Bros., Ltd

MANHOLE COVER. Cast-iron covers are fixed at the surface level, to allow passage of traffic. There are many patterns, for paved areas, for roadways, and for use within buildings. (*See* B.S. 497 : 1945, for comprehensive range of covers and fittings.) They are all made with a frame embedded around the opening and a cover



MANHOLE COVER. Fig. 3. "Friary" recessed cover and frame: seal 1 in.; overall depth 3¼ in.; cover recessed 1¼ in.

having a projecting lip on the underside is fitted into it. The projecting lip of the cover, in conjunction with the trough of the frame, forms a seal, and the space between them should be filled with manhole grease. A typical manhole cover and frame which may be used anywhere is shown by Fig. 1.

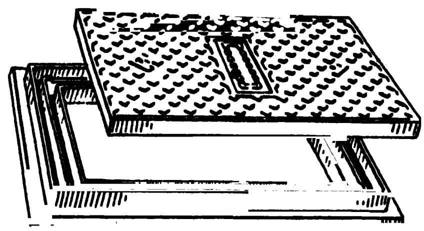


Fig. 4. Double-grooved manhole cover and frame for use over stoneware channel.

This type of cover can be fitted with brass corner screws, a pad to receive them being cast outside the seal. Such manhole covers are obtainable in about 24 sizes, from 6″ × 6″ to 60″ × 18″ clear opening, with a number of intermediate sizes 24″ wide; the thickness of cover varies from ¼″ to ½″, and the weights of cover and frame from 17 lb. to nearly 3 cwt. Keyholes are provided to receive the lifting keys.

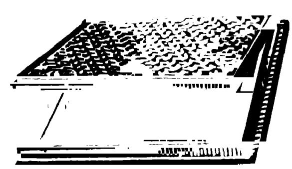


Fig. 6. Flat top, hinged and locking cover with frame.

Other types of cover are provided with hand-holes for lifting (Fig. 2), but these are not so desirable; the lifting bars bridging the hand holes are inclined to rust away.

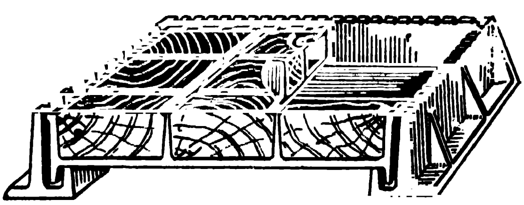


Fig. 7. Roadway cover and frame for heaviest traffic: elm blocks and single grease seal.

Recessed Top Covers. It is frequently desirable to fill in the covers with the floor material such as tiles, terrazzo or wood blocks; the recessed top manhole cover is marketed for this purpose (*see* Fig. 3). The cover has keyholes for lifting, and can be obtained with brass or gunmetal screws for holding down the cover.

Double Seal Covers. Many engineers favour a double-seal manhole cover for use over stoneware channels. This type is shown by Fig. 4. A better pattern is that having an inner and outer cover (Fig. 5), and is obtainable with both flat or recessed top cover. Such covers were frequently used over stoneware channels where inside buildings, but the London by-laws now call for a bolted cover immediately over the channel.

Hinged and locking covers with flat tops (Fig. 6) are frequently used, but there is always a danger that the cover may be broken if it is let down too heavily.

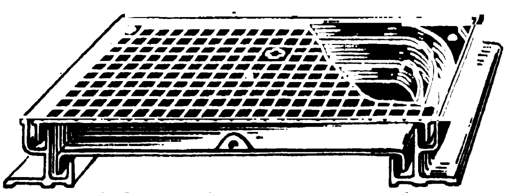


Fig. 5. "Rotunda" double cover and frame with inner grease-sealed lid; seals 1¼ in. deep.

Roadway Covers. Roadway covers and frames are made to withstand the heaviest of traffic. Two types of these fitments are here illustrated. The pattern shown in Fig. 7 is available in sizes from 18″ × 18″ × 4″ deep to 36″ × 24″ × 5″ deep, and the weights vary from 1 cwt. 3 qr. 14 lb. to 5 cwt. The cover illustrated is provided with elm blocks, but may be obtained without the blocks, so that the spaces can be filled in with granolithic or concrete. Other types of rectangular covers have flat studded tops.

Roadway covers are also made circular, 18½ in. and 21½ in. diameter (Fig. 8), with square bases for bedding; they are obtainable fitted either with elm blocks (Figs. 7 and 8) or ventilating openings.

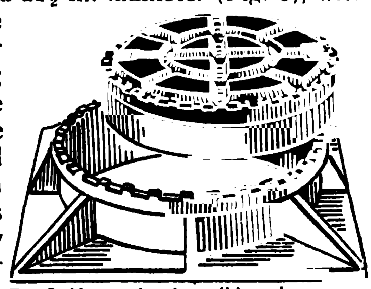
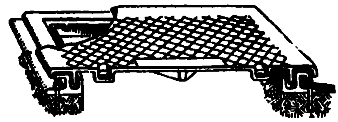


Fig. 8. Heavy circular solid roadway cover and frame fitted with twelve elm blocks. (Figs. 5-8, Burn Bros. Ltd.)

Showerproof Covers. These (Fig. 9) are used on asphalt flat roofs; they cannot be employed elsewhere because of the protecting upstand.



MANHOLE COVER. Fig. 9. Showerproof cover and frame for fixing in asphalt roofs: flange to receive asphalt; raised above flat.
Burn Bros., Ltd.

Watertight Covers. These are made by special methods, their faces and joints being machined. If it is essential for a cover to be watertight the fact must be mentioned when ordering.

Size. The size of the manhole cover is most important, the common fault being to have it too small. It should be remembered that a man has to enter the manhole to work. Generally, covers over shallow manholes should be the full size of the manhole; whilst for deep manholes (5 ft. or more) the cover may be 24 in. × 23 in., the manhole top being oversailed to receive it.

MANLID and MANHOLE: To Boiler. Manholes are provided in domestic hot water boilers (in the shape of an oval or circular hole) as means of access to allow for the removal of " fur " and mud, and general boiler cleaning. Sufficient manholes should be provided for access to all parts of the boiler, and the manhole should be large enough for the entry of scrapers and other cleaning tools.

The position depends largely upon the type of boiler, those in independent domestic hot water boilers being generally situated at the top and bottom of the side of the boiler. In the case of fireback boilers of the arched type the manhole is situated on the top of the boiler; while in the boot type it may be either on the flat or the vertical face, or on both.

The manlid, or circular or oval flange for closing the manhole, is secured by a bridging piece inside the boiler, to which is connected a threaded bolt extending through the manlid. The latter is tightened down to the boiler by means of a nut on the threaded part of the bolt. A suitable packing of sheet rubber or other appropriate material is placed between the manlid and the boiler to prevent leakage.

If the manlid of a fireback boiler is likely to be exposed to the fire and hot gases, it should be suitably protected by means of an iron plate, or a layer of fireclay or asbestos.—*W. J. Woolgar, M.R.San.I.*

See Boiler: (3).

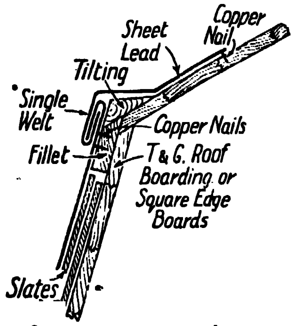
MANOMETER. *See* Pressure Gauge.

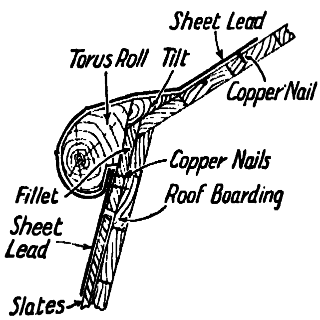
MANSARD: or Curb Roof. A roof with two pitches, the lower pitch being nearly vertical and the higher roof having a slow pitch. This roof is used mainly where it is required to utilize as bedrooms, etc., the space above the ceiling, which would not be possible with a roof of ordinary pitch.

The point where the higher roof sits on the lower roof is known as the curb; hence, the alternative name for this type of roof. The making watertight of this meeting point is the main concern of the plumber in the mansard type of roof, although if the roof comes against a wall it will be necessary to use lead flashings here. Fig. 1 shows how the problem is dealt with at the curb by means of a welt.

The apron should be fixed first, and be securely nailed close up to the lower edge of the curb; the underlap may then be nailed in position and made tight to the apron by means of a single welt. A great advantage when making this type of joint is to plant a tilting fillet on the edge of the curb, against which the edges of the lower slates can abut. The apron should also be nailed to the fillet, as it will be found that it forms a solid backing for the welt. In cases where this fillet is not fixed the slates are taken to the angle of the curb and the apron rests on them. This will result in the slates tilting and they will in time become loose.

A more imposing type of finish to the mansard is to use a torus roll; this roll sometimes has additional mouldings under-





MANSARD. Figs. 1 and 2. Watertight lead curbs to mansard roof: (left) use of welt at curb; (right) plain torus roll.

neath, although these are not to be recommended. It is difficult in such case to make the lead tight, and in time it will sag away and may be blown up by the wind. Fig. 2 shows the usual type of roll used. It is not advisable in this case to make the roll cover and apron in one piece; they should be nailed to the lower-pitch roof before the roll is fixed in position, the roll covering being allowed to hang. The wooden roll should now be nailed in place; the lead should be folded in position over the roll and tilt, continue up the roof boarding for about six inches, and be nailed on the top edge. This method is far superior to any other.

When the curb comes against a wall it is not advisable to step the lead covering into the brickwork; it should simply be turned against the wall to a height of three inches, and completed by means of step flashings (*see* Flashing).—*J. Malpass, M.R.San.I.*

MARINE SANITARY ENGINEERING. *See under* Ship Plumbing.

MECHANICAL EXTRACTION SYSTEM. System of ventilation in which the vitiated air is exhausted from a building by a fan discharging to the atmosphere outside. It is described under the heading Ventilation. *See also* Duct System; Fan; Plenum Heating.

MENSURATION AND OTHER CALCULATIONS FOR THE PLUMBER & HEATING ENGINEER

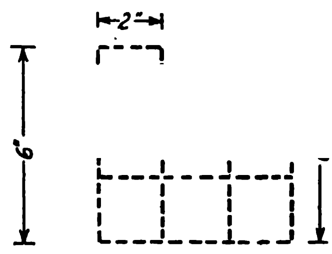
By J. St. Denys Reed

In this article the object is to aid the student and the craftsman in making use of the many formulae and other practical data provided in this Encyclopedia. Examples have been chosen from various departments and trades. Refer *also* to Areas; Arithmetic; *and* such articles as Air; Pressure; Temperature, etc.

In the article on Arithmetic, earlier in this work, examples are given of simple calculations, including fractions and decimals; indexes, powers and roots; and logarithms. Under the heading Areas and Volumes, too, will be found useful formulae and constants, with practical examples of calculations. In the present article it is proposed to deal further with calculations needed by the Plumber and Heating Engineer, taking as examples some of the data and formulae offered throughout this work.

Ducts. In the article on Friction a graphic comparison is made between ducts having the same cross-sectional area but a different shape—the result being a great difference in contact area and hence in frictional resistance offered to the flow of gases. Duct A is circular, with a diameter of 3 ft. 4½ in.; Duct B is square, each side being 3 ft. long; Duct C is rectangular, 9 ft. × 1 ft. The area of each section is 9 sq. ft., but the friction areas in contact with air per foot of length are, respectively, 10·6 sq. ft., 12 sq. ft., and 20 sq. ft. The author points out that in comparing relative capacities of pipes it is the square root of the fifth power of the diameter that must be taken into account. Thus, although nine pipes of 2 in. diameter are apparently equal to one of 6 in. diameter (square pipes being taken for ease of comparison), in practice it would require sixteen pipes of 2 in. diameter to serve the same duty as a single one of 6 in. diameter (actually the figure is 15·73). This is because the smaller pipes have proportionately a much greater area of surface contact. (*See* Figs. 1 and 2 on this page.)

It is often necessary to alter the shape of a duct from square to round while preserving the same cross-sectional area; in Table II, page 345, circles of 1 in. to 60½ in. diameter are given, with sides of squares of equivalent area. Thus, the example above, a circle of diameter 3 ft. 4½ in. has an area of 1288·25 sq. in., and to be of equal area a square



MENSURATION. Figs. 1 and 2. Owing to increase of contact area, nine pipes 2 in. × 2 in. (right) are needed to serve same duty as one pipe of 6 in. × 6 in. (left).

must have sides measuring 35·89 in. diameter.

Again, in practical work, it is required to know the sizes of duct necessary to deliver a given volume of air, the initial velocity being known. Thus, a fan delivers air at 2,000 ft. per minute and it is required to reduce the velocity to half and deliver the same volume (the fan outlet being 20 in. diameter): What should be the diameter of the taper enlarging piece to reduce the velocity to 1,000 ft. per min.?

On referring to Table II, page 345, it is seen that the area of a duct with a diameter of 20 in. (circular) is 314·16 sq. in.; looking down the column we find that a duct of 28 in. diameter has an area of 615·75 sq. in. Again, assume that it is required to deliver air in equal volume at eight outlets. Refer to Table I, page 344; in the first column opposite the required no. of outlets (8) is given in col. 3 the factor 0·397. The initial diameter (say 28 in.) is to be multiplied by this factor:

$$28 \times 0{\cdot}397 = 11{\cdot}11,$$

so that the diameter of each outlet will have to be approximately 11 in.

Conversely, if we desired to know the size of duct to serve three outlets of 12 in. diameter, col. 2 of the same Table, opposite 3 in col. 1, gives the factor 1·63. Then:

$$12 \times 1{\cdot}63 = 19{\cdot}56,$$

and the duct must be 19½ in. diameter.

Suitable dimensions of ducts depend upon volume of air to be passed and the velocity at which the air is to travel (*see* Duct Systems). Volume (in. cu. ft./min.) divided by velocity (in ft./min.) equals area of duct required in ft. Applying this formula to the case mentioned above:

A fan delivers air at a velocity of 2,000 ft./min.; what should be the cross-sectional area of the duct to deliver such air at the rate of 1,000 cu. ft./min.?

$$\frac{\text{Volume required (c.f.m.) } 1{,}000}{\text{Initial velocity (f.m.) } 2{,}000} = 0{\cdot}5 \text{ sq. ft.}$$

If the initial velocity is 1,000 ft./min. and the volume to be delivered remains as in the first example (1,000 c.f.m.) the calculation gives:

$$\frac{\text{Volume required } 1{,}000}{\text{Velocity } 1{,}000} \quad 1 \text{ sq. ft. area}$$

It is worth noting that Table I (page 344) quoted earlier enables area of ducts to be ascertained instead of diameter if desired.

Cylinders, Pipes, etc. The heating surface of piping can be calculated from the Table given in page 206. Thus if the nominal diameter is 1 in. (wrought pipe), multiplication by the factor 0·33 will give the surface in sq. ft. per lineal foot of piping.

$$25 \text{ lineal ft.} \times 0{\cdot}33 = 8{\cdot}25 \text{ sq. ft.}$$

Conversely, if the heating surface required for a calorifier is 7 sq. ft., the length of piping in 1¼ in. diameter needed is given by

$$\frac{\text{Heating surface 7 sq. ft.}}{\text{Factor } 0{\cdot}43} = 16{\cdot}28 \text{ lineal ft.}$$

It is to be noted that these factors apply to wrought pipes of the nominal diameters stated. The surface area of the convex portion of a cylinder is found by the formula (*i.e.* excluding the ends):

Height × Circumference = Area of convex portion.

For an example *see* page 59, under the heading Areas & Volumes.

The contents of a cylinder are obtained by the formula given in page 60:

Volume in cu. ft. × 6¼ (gal. water in one cu. ft.) = Contents in gallons of water.

The approximate capacity of a cylinder as used for hot water supply can be read directly from the Table in page 284.

The amount of water contained in piping is given by the Table in page 258, for diameters of ½ in. to 6 in. Thus, for piping of 1¼ in. nominal diameter the amount in gal. per lineal foot is 0·053.

Thus 230 ft. run of 1¼ in. pipe × ·053 = 12·19 gal.

Heating Calculations. Since in every main article on Heating in this work the authors have given the appropriate data and formulae for calculations, with worked-out examples, there is no need for extended explanations here. The basis of all such calculations is the British Thermal Unit (the quantity of heat required to raise the temperature of 1 lb. water through 1° F.). It is interesting to note here that to evaporate 1 lb. of water about 1,000 B.Th.U. are required. In practical work this has an important bearing on the warming-up period of a building, since a newly constructed house will contain much moisture in the walls, etc., which may take several months to dry out; *see* Heating: (1). In calculations relating to public buildings such as churches, halls, theatres, etc., the amount of heat provided by the congregation or audience has to be taken into account; as shown, an adult. dissipates from 215–436 B.Th.U. per hour.

Heat Loss. In calculating the heat requirements of a building the amount of heat lost or gained by transmission through the walls, floor and ceiling must be found out; also the amount of heat needed to warm the ventilating air; *see* Heating: (1).

Coefficients of heat loss have been established for the principal materials used in building construction, and the value of this coefficient (known as *K*) is given in the Heat Loss Chart facing page 527. *K* represents, then, the B.Th.U. per sq. ft. per hour per ° F. difference in temperature. The value of *K* for a 4½-in. brick wall, unplastered, is 0·5; of a tile or slate roof, open underneath, 1·00; of corrugated steel sheets, unlined, 1·80. It is a simple matter to calculate the heat loss by the aid of the instructions given under that heading.

Head of Water. A stationary body of water exerts pressure by virtue of its weight (*see* Hydraulics), and the height of the free surface above any given point is the static head at that point. The pressure increases with the depth or head, and is determined by the vertical height of the column of water. The density of the water, or weight per unit volume, affects the pressure, and depends on the temperature of the water. Generally the standard weight is taken as 62·36 lb. per cu. ft., this being the weight at a temperature of 62° F. The pressure per sq. in. of surface is 0·433 lb. per ft. of vertical height. In practical work, where accuracy to the third decimal place is not necessary, the standard weight can be taken as 62·4 lb. per cu. ft.

Water in an open-topped tank 10 ft. above the boiler it feeds exerts a pressure of

$$10 \times 0{\cdot}433 = 4{\cdot}33 \text{ lb. per sq. in.}$$

of boiler surface (on the top plate of the boiler). The water within the boiler also exerts pressure, so that at a depth of 1 ft. below the top plate the pressure would be increased by a further 0·433 lb. per sq. in.

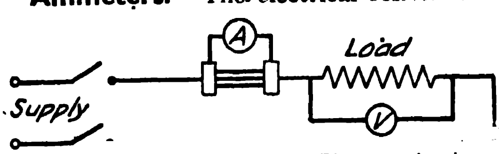
METERS: ELECTRIC, GAS AND WATER

By R. A. Baynton, A.M.I.E.E.; G. A. Hill, M.Inst. Fuel; and E. H. Vick, A.M.Inst. C.E.

In the first of this group, Mr. Baynton discusses types of electrical measuring instruments. Gas meters are dealt with next, with practical notes (for other information see Gas Fitting). Water meters are the subject of the third article. In this connexion the reader should refer to Venturi and to the Water group.

The type of an electric meter is denoted by a prefix (thus, ammeter—an instrument for measuring amperes, or current—and voltmeter, an instrument for measuring volts); or by a qualifying word (*e.g.* supply meter and kWh.—*i.e.* kilo-watt-hour meter). With one exception ammeters and voltmeters are fundamentally the same in their operations and will therefore be considered together. An ammeter is, however, connected *in* the line in which the current is to be measured (so that the whole or part of the line current passes through the meter); but a voltmeter is connected *across* the line where the voltage difference is to be determined (*see* Fig. 1).

Ammeters. The electrical resistance of an ammeter is low, so that unless the resistance of the load is also very low the introduction of the ammeter into the circuit does not appreciably reduce the line current. The current that can be passed through the ammeter without damage depends on the type of instrument; thus for a moving coil instrument (*see* latter) it is about 5 amperes and for a moving iron instrument about 100 amperes. The range of all types of ammeters can, however, be increased by the use of shunts, a shunt being a resistor having a resistance of such a value that only a definite proportion of the line current passes through the instrument, the remainder passing through the shunt. By using a number of shunts the range of the instrument may be extended indefinitely, so that currents of a thousand amperes or more may be read on an instrument that will also register only a few amperes. In commercial ammeters it is now usual to incorporate the shunts in the instrument itself. A multi-range

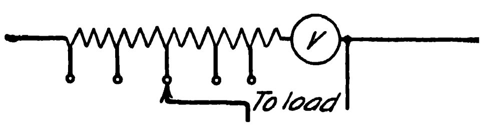


METERS: ELECTRIC. Fig. 1. Diagram showing how an ammeter is connected in the line of current and a voltmeter across the line.

instrument may have a built-in range switch, or a common terminal (C) and a number of other terminals suitably marked. In the first case, with the circuit dead, connexion is made to the two terminals and the switch set to the appropriate range; in the second, one connexion is made to the common terminal and the other to the required range terminal.

If the likely magnitude of the current is unknown the switch must be set at, or connexion made to, the highest range. The range being then altered progressively, step by step, until the most suitable range has been found. If this precaution is not taken the instrument may be burnt out.

Voltmeters. As has previously been stated, a voltmeter is connected across the circuit; if an ammeter (a low resistance instrument) were treated in this way, the current through it would in general be so high that the instrument would be burnt out, but an ammeter can be converted into a voltmeter by connecting in series with the operative part of the instrument a resistance of such a value that for the rated voltage the current passing through the instrument gives full scale deflection. By using a number of series resistances the range of the instrument may be varied, the current flowing in the instrument to give full-scale deflection being in all cases the same. (*See* Fig. 2.) The resistance may



METERS: ELECTRIC. Fig. 2. Series resistances used to vary voltage range of a voltmeter.

be incorporated in the instrument; or an external volt box or potential divider may be used.

The following types of instruments are in common use:

Moving Coil. Consists of a coil lightly pivoted between the poles of a permanent magnet. Current passing through the coil causes it to rotate against a control spring. The direction of rotation depends on the direction of current flow. These instruments may be constructed to register only when the current is flowing in one direction; or, in the case of centre zero instruments, to show both the direction and magnitude of the current.

Moving Iron. In these an iron plunger or disk (armature) is attracted by the magnetic field set up by the current passing through a fixed coil. As the coil does not move, and current does not have to pass to it via delicate control springs, it may be wound of much heavier gauge wire than the coils of the previous type of instrument. Consequently, moving iron instruments can be designed to carry quite heavy currents without the use of shunts. The limit is about 100 amperes. Early moving iron instruments were not very accurate, but modern instruments of absolute accuracy can be obtained. There are, however, on the market instruments of very dubious accuracy intended for battery testing and for use of wireless amateurs. M.I. instruments always deflect in the same direction, irrespective of the direction of current flow.

Dynamometer Instruments. Have a moving coil of light gauge wire and a fixed coil of heavier gauge. Both coils carry current, and the instrument deflects in only one direction.

Hot-wire Instruments. The needle is deflected (through suitable gearing) by the expansion of a wire heated by the passage of current. Not much used at the present time.

Induction Type. Depends for its action on the reaction between the magnetic field set up by a current in a fixed coil and the current induced in a light metal disk.

Moving coil instruments can only be used on D.C., Induction instruments on A.C. Moving iron, Dynamometer, and Hot-wire instruments may be used on either A.C. or D.C. All the above instruments are usually fitted with zero adjusters and, before using, the pointer should be brought to zero.

Wattmeter. This is an instrument for measuring electric power, and com-

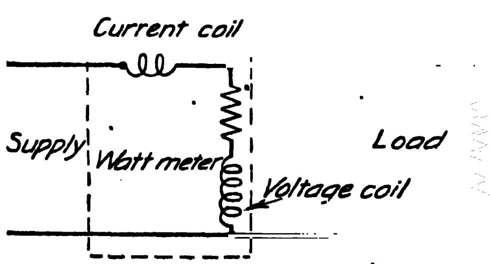


Fig. 3. Single-phase wattmeter connected in circuit.

prises two circuits—one for carrying current, and the other for carrying a current proportional to the voltage (the voltage coil). Fig. 3 shows a single-phase wattmeter connected in circuit.

Supply Meters. These are instruments that integrate the amount of current or power consumed over a period of time. The main types are electrolytic meters, Aron clock meters, and motor meters. Electrolytic meters can only be used on D.C. circuits and for this reason, and also because of certain inherent defects, they are rapidly disappearing.

The Aron meter consists essentially of two pendulums, the bobs of which carry a fraction of the circuit current, oscillating in fields that carry a fraction of the circuit current. The forces of attraction and repulsion between the fixed and moving coils are proportional to the watts in the circuit metered, and the connexions are such that one of the pendulums is accelerated whilst the other is retarded. The motion of the pendulums is conveyed to a train of gearing.

Motor meters now constitute the most important class, and comprise a simple motor which develops a torque proportional to the quantity to be integrated (watts, amperes, or volt-amperes, or multiples of these). The speed of rotation of the motor disk, which is resisted by an eddy current brake, is proportional to the quantity being measured; the total number of revolutions of the disk communicated, by gearing to a series of dials, can be made (by calibration) to show the total power (or other quantity) consumed over a given time.

Induction motor meters are fundamentally similar to the non-integrating meters of the same type, except that the control spring is replaced by an eddy current brake and that the readings are integrated by gearing as with the other types of supply meter. Induction motor meters can only be used on A.C.

METERS, GAS: TYPES, SIZES AND CONNEXIONS

By G. A. Hill, M.Inst.Fuel, Instructor in Gas Engineering, Redhill Technical College

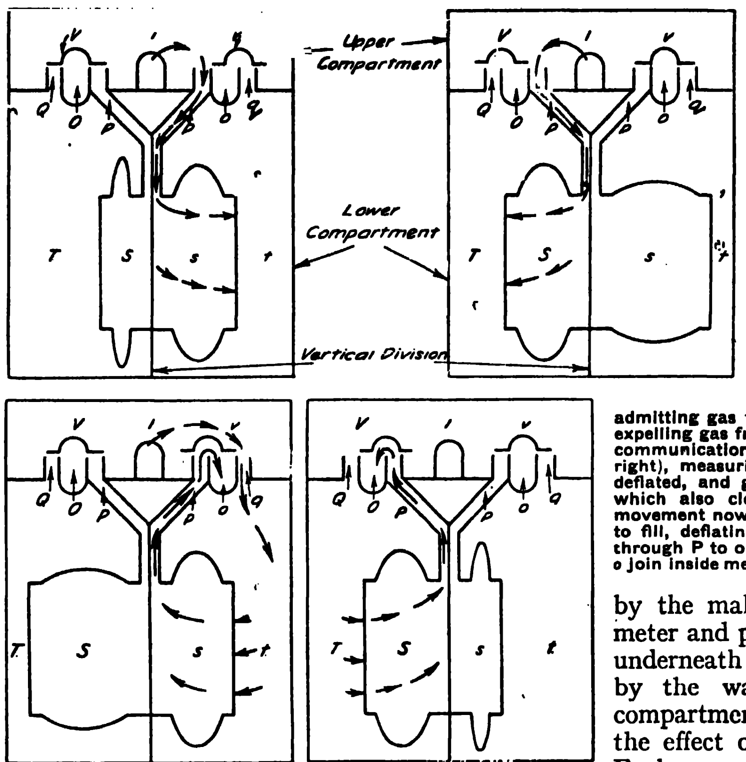
Meters used for domestic consumers are of two types, viz., dry and wet, though the latter type has been discontinued to a large extent owing to its higher initial cost and the fact that regular and periodical attention is required to maintain the water level. The dry meter has been developed into a compact, light and reliable means of measuring gas. Since the advent of dry gas on some large undertakings, it is essential that the gas should not come into contact with water; a dry meter is therefore imperative.

Dry Meters. The dry meter consists of a rectangular tinned iron box with a small upper compartment and a larger lower compartment (which in turn divides laterally into two equal compartments). Fixed to the partition of the lower compartment, one on each side, are two collapsible bellows formed of circular metal plates and leather. The top compartment houses two sets of valve ports and valves, communicating with the inside of the bellows and with each lower compartment outside the bellows. Cranked arms transfer the motion of the bellows to two vertical rods passing through stuffing boxes and into the top compartment where, by a system of levers and a crank, the train of gears forming the index and the valves is driven. Reference to the diagrammatic illustrations (Figs. 1–4 in p. 696) will explain the sequence of working.

Where it is desired to employ a prepayment slot meter a suitable device is added to the side of the meter: it consists of a valve closing the inlet to the meter, this valve being connected with a quick-thread screw. Insertion of a coin links up the screw with the lever on the outside, and on turning the lever the valve is raised off its seat. The more coins that are used, the further the valve will be lifted from its seat. The screw is also connected with the driving mechanism: this latter, when the meter is working, turns the valve-operating screw in the reverse direction to which it was turned by the coin, thus gradually closing the valve. Variations of this mechanism enable either shillings or pennies to be used at will.

Sizes and Connexions. Sizes, capacities and connexions of some dry meters are given in the Table printed in page 697.

Both the older types of "lights" meter and the later high capacity meter are



METERS : GAS. Figs 1–4. Sequence of working of dry meter. 1 (top left), gas entering top compartment through inlet *I* passes down post *p* (post to inside of diaphragm), inflating bellows (measuring chamber inside diaphragm) ; the inflation causes gas in casing *t* (measuring chamber outside diaphragm) to be forced out through post of *q* (post to outside of diaphragm) through slide valve *v* to outlet post *o*. 2 (top right), bellows *s* are fully inflated and valve *v* is closed at *p* and *q* ; gas now enters bellows S through post P, expelling gas in T through Q into outlet O. 3 (bottom left), further movement of meter mechanism opens post *q*, admitting gas to *t*, deflating bellows *s*, and expelling gas from meter, since post *p* is in communication with outlet *o*. 4. (Bottom right), measuring chamber *s* is now fully deflated, and gas to *t* is cut off by valve which also closes *p* to outlet. Further movement now opens post Q, and T begins to fill, deflating S and expelling gas in S through P to outlet O. Both outlets O and *o* join inside meter, forming common outlet.

given here. The capacity of the " lights " meter is rated by assuming that one gas light requires 6 cu. ft. of gas per hour : thus a 10-light meter has a capacity of $10 \times 6 = 60$ cu. ft. per hour. The main difference between the " lights " and high capacity type is that the latter has increased size of valves and ports and a modified form of bellows. These modifications allow a larger volume of gas to be measured for the same size of case. A striking difference in size of case will be noticed for any given capacity. Meters up to 700 cu. ft. per hour are fitted with brass unions for lead pipe connexions ; above this capacity flanged iron connexions are used. It is customary to by-pass the larger size meters, which are not usually carried in stock, so that in case of meter breakdown the supply of gas to the consumer may be continued while repairs are effected.

Wet Meters. The wet meter consists of a cylindrical iron casing with horizontal axis through which passes a spindle carrying the measuring drum. The drum is made of pure tin and is divided into four compartments shown diagrammatically in Fig. 5. The meter casing is filled with water to just above the spindle, at a height set by the makers. Gas enters the meter and passes through a tube, underneath an apron piece sealed by the water, and into each compartment in turn ; this has the effect of rotating the drum. Each compartment of the drum has an opening to the outer casing ; as each compartment fills and the drum rotates, this part is unsealed by the water and the gas passes out into the outer casing and thence away from meter. The gas is expelled from the full compartment turning the drum round, thus gradually submerging the first compartment. Fig. 5 makes the action clear.

Very large meters used by gas companies to measure the " make " of gas differ in type. The meter may be of the wet type, similar in principle to that already described ; but as these are very bulky and have other undesirable qualities, smaller

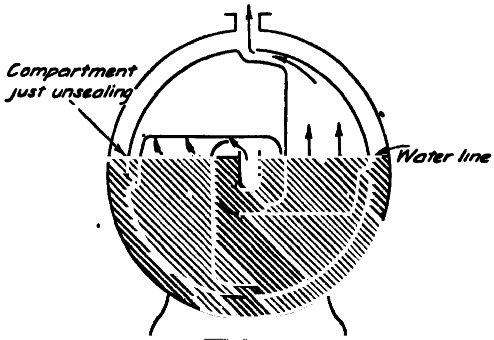


Fig. 5. Wet meter : iron casing enclosing rotating drum which measures gas by compartments ; the latter are water sealed until rotation unseals outlet post.

Gas Meters : Sizes, Capacities and Connexions

Size	Capacity cu. ft. per hour.	Height ins.	Breadth ins.	Depth front to back, ins.	Size of connexions, ins.
10 light ..	60	19¼	14⅞	10¾	1
No. 3	60	16⅝	12⅞	8¾	¾
HC/100 ..	100	11⅞	9¾	7¼	¾
HC/200 ..	200	15¼	12⅛	8⅞	1
60 light ..	360	34	27¼	20¾	1¾
HC/400 ..	400	18¾	15⅞	14	1½
HC/700 ..	700	25½	22	15	2
150 light ..	900	51½	42	29	3 flanged
200 light ..	1,200	56¾	42½	30	3½ flanged
HC/1,200 ..	1,200	29	29½	18⅛	3 flanged

and more suitable meters have been devised. There is a rotary meter in which, after passage through ports, the gas is impelled against the vanes of a rotating disk. In another case two delicately balanced vanes are geared together in a casing, the vanes working in with each other and being so shaped that the gas pressure turns the two vanes round in opposite directions (Connersville Meter).

For very accurate laboratory and testing purposes a wet meter of special construction is used, this type having great accuracy. There are other types (*e.g.* Flow meters), but these are comparatively rare, and are only met with in the laboratory or for testing purposes. For further information *see* Gas Fitting.

METERS, WATER: PRINCIPLES & VARIETIES

By E. H. Vick, A.M.Inst.C.E.

Water meters are used for registering the amount of water supplied to private consumers when water is sold to them by bulk. They are also installed at various points in the town's mains for checking the supply in each district and for detecting where waste occurs through leaky pipes and fittings.

There are a large number of patented types in use, and the choice of the best meter for any particular purpose is best left to the specialist firms that manufacture them. The more usual types consist of a small casting containing two pistons working in cylinders of known capacity. The water enters each cylinder in turn, and the movement of the piston is transmitted by mechanism to the dials on the face of the instrument. The meter is read in a similar manner to a domestic gas meter.

For domestic supplies it is essential that the meter works noiselessly, and that it is calibrated accurately. For waste water detection, however, accuracy in measuring the larger flows is not so essential, but the meter must measure the total quantity passed over a period of about 15 minutes, down to very small flows of about 1/10 gallon per minute.

Meters are usually made to suit any size pipe from 1 in. to 6 in. diameter. A 1-in. diameter meter, for example, will measure accurately flows as low as 5 gallons per hour.

Venturi Meter. For measuring large flows a Venturi meter is usually installed. These meters record automatically on a chart, the rate of flow at any time, and also register the total quantity of water passed. The Venturi meter itself is placed in the pipe line and consists of a short length of pipe converging to the throat (*see* Fig. 1), and a longer divergent cone gradually expanding to the full diameter of the pipe. (*See* Venturi for principle.)

Water flowing in the direction of the arrow C gains in velocity as it reaches the throat but loses head. After leaving the throat it loses velocity but regains nearly all the original head. The pressure at $A = pa$ and the pressure at $B = pb$, thus there is a difference of pressure between the upstream side and the throat equal to h.

Let A = the area of the upstream portion $= \frac{\pi}{4}D^2$

Let a = the area of the throat portion $= \frac{\pi}{4}d^2$

Then the quantity passing at $A = Q = AV_1$
The quantity passing at $B = Q = av_2$

and since it can be proved that $h = \frac{V_2^2 - V_1^2}{2g}$

it will be seen that if the diameters of the throat and upstream section are accurately known the quantity passing can be determined by measuring the difference of head *h*.

Example. Let D = 6 in. then A = 28·27 sq. in. = 0·196 sq. ft.
Let *d* = 4 in. then *a* = 12·57 sq. in. = 0·0873 sq. ft.
Let *h* = 5 ft.

$$\text{Then } 5 = \frac{V_2^2 - V_1^2}{64 \cdot 4} \text{ or } V_2^2 - V_1^2 = 322$$

$$\text{But } Q = AV_1 = aV_2$$

$$\therefore V_1 = \frac{Q}{\cdot 196} \text{ and } V_2 = \frac{Q}{\cdot 0873}$$

$$\therefore \frac{Q^2}{(\cdot 0873)^2} - \frac{Q^2}{(\cdot 196)^2} = 322$$

$$\text{or } 131 \cdot 5Q^2 - 26 \cdot 3Q^2 = 322$$

$$\therefore 105 \cdot 2Q^2 = 322$$

$$Q^2 = 3 \cdot 03$$

$$\text{or } Q = 1 \cdot 74 \text{ cu. ft. per sec.}$$

$$\text{or } Q = 940{,}000 \text{ gal. per day}$$

Venturi meters are constructed with annular pressure chambers at the upstream end and at the throat, from each of which small copper pressure pipes are taken to the recorder (Fig. 2). The recorder may be placed any reasonable distance from the Venturi tube, and may be either of the water type or the mercury type.

The pressure pipes A are led to the bottom of the float columns B. Floats working in these colums transmit the difference of head *h* by means of wires to the recorder C. The recorder consists of a drum on which is mounted a chart ruled in horizontal lines for the rate of flow and in vertical lines for time. The drum is rotated by a clock, and a pen actuated by the float wires records the rate of flow at any time. By means of integrating mechanism the total flow is recorded on dials. The float columns may contain either water or mercury; in the latter case the height of the columns will be much less than with water.

The chart may be calibrated for daily or weekly recordings. Venturi meters may be installed in any size main, and have been used on mains up to 10 ft. diameter. A length of 40 diameters of straight pipe is necessary on the upstream side of the meter.

METRIC SYSTEM. A decimal system of weights and measures. The basic unit is called the metre and was supposed to be one ten-millionth of the length of a quadrant of the meridian (*i.e.* of the earth's surface between the pole and the equator, at sea level). Actually there proved to be a slight discrepancy, and the "standard metre" is the length of a metal bar kept in the French national archives.

Linear and Superficial Measurement. Subdivisions and multiples are indicated by the use of a prefix before the word metre, as follows:

10 millimetres (mm.)	equals	1 centimetre
10 centimetres (cm.)	,,	1 decimetre
10 decimetres (dm.)		metre
10 metres (m.)		decametre
10 decametres (Dm.)		hectometre
10 hectometres (hm.)		kilometre
10 kilometres (km.)		myriametre

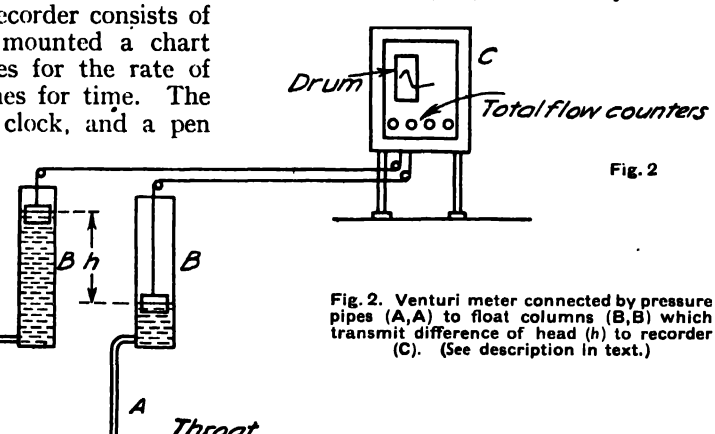
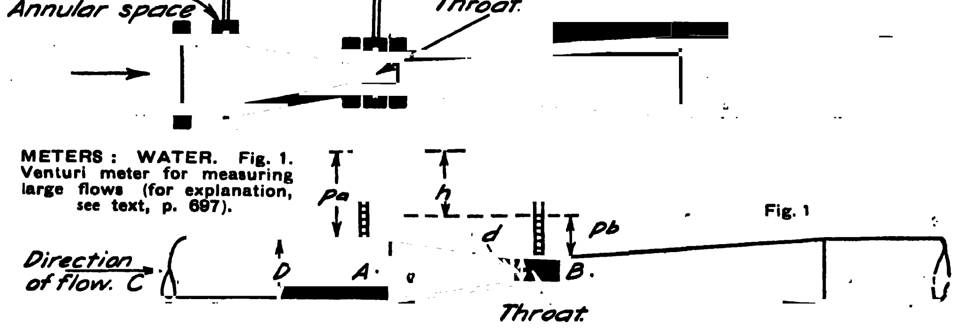


Fig. 2

Fig. 2. Venturi meter connected by pressure pipes (A,A) to float columns (B,B) which transmit difference of head (*h*) to recorder (C). (See description in text.)



METERS : WATER. Fig. 1. Venturi meter for measuring large flows (for explanation, see text, p. 697).

Fig. 1

One of the great merits of the metric system is that it is based on the decimal system. The metre can thus be subdivided into the decimetre (*tenth*), centimetre (*one-hundredth*) and millimetre (*one-thousandth*). Latin prefixes are used for sub-divisions, and Greek prefixes for multiples. Multiples of the metre are the decametre (10), the hectometre (100), the kilometre (1,000), and the myriametre (10,000). Similar units are used for square measure and cubic measure; while a parallel series, based on the litre, is employed for volume. Weight is based on the gram. The various units are linked up; thus the litre is approximately equivalent to 1,000 cu. centimetres (actually to 1,000·028); the gram has the same weight as a cubic centimetre of water. A litre of water weighs approximately 1,000 grams (or 1 kilogram).

In superficial measurement 100 sq. metres equals one are, and 100 ares equals one hectare. For most measurements the metre is the unit: centimetres or millimetres are used for small distances, and for roads or great distances the kilometre. The number of metr is written at the left of a decimal point and the subdivisions at the right. Scales on drawings are indicated by simple fractions. Thus, the scale which in France or Germany corresponds to ⅛ in. to 1 ft. is expressed as 1/100 or 1 : 100—immediately conveying the information that 1 metre equals 100 metres and 1 centimetre equals 100 centimètres—that the drawing is, in fact, 1/100 full size.

Volume. The litre is the unit of volume and equals 1,000 cu. cms. The relations of the units are as follows:

10 millilitres (ml.)	equals	1 centilitre
10 centilitres (cl.)	,,	1 decilitre
10 decilitres (dl.)	,,	1 litre
10 litres (l.)	,,	1 decalitre
10 decalitres (Dl.)	,,	1 hectolitre
10 hectolitres (Hl.)	,,	1 kilolitre

The hectolitre is the unit commonly employed for large quantities of materials such as grain, fruit, and liquids.

Weight. The gram is the unit of weight, and is the weight of 1 cu. centimetre of distilled water at 39·2 deg. F. The relations of the units are the same as those given above for volume, 10 of each equalling 1 of the higher unit. These units are: milligram (mg.), centigram (cg.), decigram (dg.), gram (g.), decagram, hectogram, kilogram (kg.), or kilo, myriagram, quintagram (q.), tonneau (t.), or tonne. The gram is for small articles, the kilo for larger objects such as groceries, and the tonne for very heavy articles. The metric tonne is approximately the weight of a cu. metre of water.

Conversion Factors

Example—
Column 1 × Multiplier = Column 2. Inches × 25·4 = millimetres.
Column 2 × Reciprocal = Column 1. Millimetres × ·039 37 = inches.

Column 1	Column 2	Multiplier	Reciprocal
Inches	Mms.	25 ·4	·039 37
Feet	Metres	·304 8	3 ·280 8
Yards	,,	·914 4	1 ·093 6
Miles	Kms.	1 ·609 3	·621 37
Square ins.	Square mms	645 ·16	·001 55
,, ins.	,, cms.	6 ·45	·155
,, ft.	,, metres	·092	10 ·764
Cubic ins.	Cubic cms.	16 ·387	·061
,, ft.	,, metres	·028 32	35 ·314 8
Lb.	Kgs.	·453 59	2 ·204 62
Cwt. (112 lb.)	Kgs.	50 ·802	·019 68
Tons	Tonnes (metric)	1 ·016	·984 2
Ft. Poundals	Ergs	·421 387	23 ·731 × 10⁻⁷
Poundals	Dynes	13 825 · 45	·000 072 33
Lb. per yard	Kg. per km.	496 ·06	·002 02
Lb. per sq. in.	Kg per sq. cm	·070 31	14 ·223
Pints	Litres	·568	1 ·76
Quarts	,,	1 ·136	·88
Gallons	,,	4 ·546	·22

Comparative Tables:

Linear Measure

1 cm. equals ·3937 in.
1 m. ,, 3·2808 ft.
1 m. ,, 1·0936 yd.
1 km. ,, 1093·633 yd.
1 km. equals ·621370 mile

Superficial Measure

1 sq. cm. equals ·1550 sq. in.
1 sq. m. equals 10·7639 sq. ft.
1 sq. m. equals 1·1960 sq. yd.
1 hectare equals 2·4711 acres
1 hectare equals ·0038 sq. mile

Cubic Measure

1 cu. cm. equals ·0610 cu. in.
1 cu. m. equals 35·31 cu. ft.
1 cu. m. equals 1·3080 cu. yd.

Volume

1 cu. cm. equals ·0338 fluid ounces
1 litre equals ·2205 gallons

Weight

1 kg. equals 2·2046 lb.
1 q. ,, ·9831 ton
1 t. ,, 9·831 ton

See Arithmetic.

METROPOLITAN WATER BOARD: THE BY-LAWS

By E. J. Ward, LL.B.

In a number of the practical articles on Plumbing and Sanitary work printed in other pages extracts from the M.W.B. By-Laws are given, or specific reference made to them. Here Mr. Ward draws attention to the most important sections. The By-Laws themselves can be obtained from the Board, together with separate "Notes" on them. See Ball Valve; Cistern; Water Closet; Water, etc.

By-laws in force at the present time are those made by the Board on July 21, 1950, under the authority of Section 16 of the Metropolitan Water Board Act 1932 for the purpose of preventing the waste, undue consumption, misuse, or contamination of water. They were confirmed by the Minister of Health and became operative on September 14, 1950. Following extracts from the by-laws are given as of importance to readers.

Application. The by-laws apply to water fittings used for conveying, delivering, or receiving water supplied by the Board, but do not require any person to alter or renew, unless defective, any fitting which was lawfully fixed in accordance with previous by-laws (By-law 5).

Pipes. Communication pipes must be of lead, lead alloy, or cast iron, and have a bore of not less than half an inch. Supply and distributing pipes shall be of suitable material and, if laid in contact with the ground, must not be of cast iron or steel (By-law 8). Pipes of lead, lead alloy, cast iron, asbestos cement, wrought iron, steel and copper must conform to the appropriate British Standards. Cast iron and asbestos cement pipes must be capable of withstanding a test pressure of at least double that which they must sustain under working conditions (13). This requirement also applies to pipes of any material not specifically mentioned (17).

Pipes of wrought iron, steel, and malleable c.i. fittings must be protected from external corrosion, and, if not part of a closed circuit, against internal also (14).

Joints in lead and lead alloy pipes must be made by means of a wiped soldered joint or by some equally efficient watertight joint (10). Connections between lead and lead alloy pipes and pipes of other metals must be made by means of a corrosion resisting screw-ferrule wiped on to the lead or lead alloy pipe, or by some equally effective method (11). At least 1½ in. of any fitting connected to a lead or lead alloy pipe by a wiped joint must be included within that joint (12).

Bends must not be constructed so as to diminish the waterway or alter the internal diameter of the pipe (18). Pipes must be adequately supported in such a manner as to avoid air locks (19), and if placed underground, not under a building, they must be at a depth not less than 2 ft. 6 in.

Stop Taps. Every supply pipe must be fitted with a stop tap inside the building, as near as practicable to the point where the pipe enters it. Stop taps, if less than 2 in. internal diameter, must comply with the appropriate British Standard, and, if over 2 in. diameter, must comply with B.S. 1218 : 1946, for sluice valves for waterworks purposes (24).

Taps and Valves. Bib, pillar, globe and stop taps of not more than 2 in. nominal size, and of the ordinary screw-down pattern must conform to B.S.1010 : 1944. Other patterns must be capable of resisting a pressure of at least 300 lb. per sq. in. and internal parts must be made of corrosion resisting alloy (26).

Ball Valves. Ball valves of the Portsmouth pattern must comply with B.S.1212: 1946 (By-law 27). High pressure, medium pressure, and low pressure ball valves of other types must be suitably stamped, and must close against test pressures of 200, 100, and 40 lbs. per sq. in. respectively (27). By-laws 28 and 29 provide for the positioning of the ball valve in the cistern and precautions, where necessary, against siphonage of water back through the valve. *See also* p. 705.

Cisterns. In general, supply pipes must discharge into a storage cistern (31), but a draw off tap for drinking water must be provided (57). Pipes and cisterns which receive and convey the Board's water must be used exclusively for it (32).

By-law 35 enumerates many materials for the construction of storage cisterns.

Mild steel cisterns of 1000 gallons capacity or less must comply with B.S.417 : 1944, for grade A cisterns (36). Storage cisterns must be of not less than 50 gallons capacity, and, if used also as a feed cistern, not less than 80 gallons (39).

Hot Water Apparatus. Every hot water storage vessel must hold not less than 25 gallons and be constructed of a suitable material (50). If made of mild steel or copper, it must comply with the relevant British Standard (51). The run of pipe from a hot water apparatus or storage vessel to a hot water tap must not exceed the limits set forth in by-law 49. These distances are 40 ft. for a ¾ in. pipe, 25 ft. for a 1 in. pipe, and 10 ft. for a pipe exceeding 1 in. internal diameter.

Pipes for conveying hot water must be of lead, copper, galvanized steel or wrought iron, or of some corrosion resisting alloy (48). Cast iron pipes of not less than 2 in. diameter may be used if suitable provision is made for expansion (48). By-laws 43 to 46 provide for regulating the supply of water to heaters, electric storage, and other hot water appliances (48).

Baths, Lavatory Basins and Sinks. Outlets must be fitted with watertight plugs (53). Every inlet to a fixed bath, basin, or sink must be distinct from and unconnected with any outlet (53).

Flushing Apparatus. This must be provided for every water closet and urinal (54). Flushing cisterns serving water closets must provide a flush of two gallons. If hand operated, a cistern servicing a urinal must provide a flush of one gallon per stall (56). Flushing cisterns must conform to British Standard 1125 : 1945.

Standpipes. A standpipe serving more than one house must be fitted with a non concussive self-closing or other suitable waste-preventing tap (58).

Water Troughs. These must each be fitted with a ball valve or similar device which must be housed in a separate compartment which can be locked (59).

Disconnection of Water Fittings. A pipe solely supplying water to a fitting which is to be permanently disconnected must itself be disconnected (60).

Notices. At least seven days' notice in writing must be given of an intention to use water (not supplied by meter) as a source of motive power, for operating refrigerators, or with a hosepipe for watering or washing gardens, horses, or vehicles in stables or garages (61).

At least three days' notice must be given of an intention to fix or alter (excluding repairs and renewals) any water fitting (62).

Testing and Stamping Fittings. Fittings used with the Board's supply must be tested and stamped to guarantee compliance with the by-laws (63), charges for testing and stamping being laid down (64).

Meters. The type, quality, construction, position, fixing, and mode of connection is set forth in by-law 65. A meter which records to within 3 per cent the quantity of water which actually passes through it is to be deemed accurate (66). Provision is made for the estimation of consumption where meters are found to be inaccurate or fail to register (66).

Penalties. A fine not exceeding five pounds may be imposed for an offence against the by-laws, and where the offence is a continuing one, an additional fine, not exceeding forty shillings, for each day the offence continues after conviction (68).

MINIMUM SPECIFICATIONS (Institute of Plumbers). The Institute of Plumbers have issued certain specifications for plumbing work, embracing the principal aspects of such work.

The reasons which impelled them to undertake this work are the following. The Ministry of Health, as the confirming authority, issue from time to time model by-laws. Local Authorities—of which there are some hundreds—seeking to obtain confirmation of their revised by-laws are inevitably guided by such models. But, partly because of local conditions and partly, it must be admitted, because of the traditional independence of local government, local by-laws tend to reflect that independence even in minor matters. It is recognized that local circumstances must influence by-laws (as, for example, the strength of water pipe because of the varying pressures). On matters determinable by unvarying physical laws, however, there should be no variations.

The greatest difficulty with which architects, builders and sanitary engineers have to cope is the fact that, even when by-laws are laid down in reasonably precise language there frequently arise difficulties of interpretation. London is, perhaps, the most notable example. The London County Council is the responsible authority for drawing up sanitary by-laws. But these by-laws are administered by nearly thirty boroughs, and there are, in consequence, many varying interpretations by the officials of these boroughs.

It may happen, for example, that a master plumber is carrying out two

adjacent jobs, one on each side of the boundary of two boroughs. Although the by-laws are the L.C.C. by-laws, he may be forced to execute identical work in two entirely different ways.

It is hoped that in time the existence of reasoned codes will have the effect of minimizing such hindrances to efficient and economical installations.

Aims of the Specifications. The problems of the Institute were, therefore:

1. To attempt to arrive at minima of sound practice.
2. To meet the position that the Ministry of Health and the local authorities cannot be expected to complicate their by-laws by including matter specifying the detailed manner in which a good craftsman should carry out his work, once the by-laws have laid down the conditions for such work.

Once by-laws are confirmed they are enforceable by penalty. The Institute draw especial attention to that position in the preamble, where they say:

"This Specification does not, in general, deal with matters regulated or covered by provisions in the general law or ordinarily in the by-laws of local authorities, to which it is supplementary. Where there are local by-laws applying to any particular work, they should always be consulted, since they, unlike this Specification—which is issued solely as a guide to sound practice for voluntary observation by plumbers—are legally enforceable."

These Specifications are thus to be regarded as a code and, generally, as the expression by experienced craftsmen of their attitude to the problems covered. They do not, of necessity, represent in all respects what the Institute in certain circumstances might regard as the best practice. They are "minima" and are compromises arrived at by a committee deliberately composed of representatives from areas with differing conditions.

No. I (revised in 1938 and 1948 after experience had made revision necessary) includes a detailed specification and drawings for the "Combined or One-Pipe System of Plumbing."

No. III, Drainage of Buildings (1948).

No. IV, Installation of Hot and Cold Water Services (under revision, 1951).

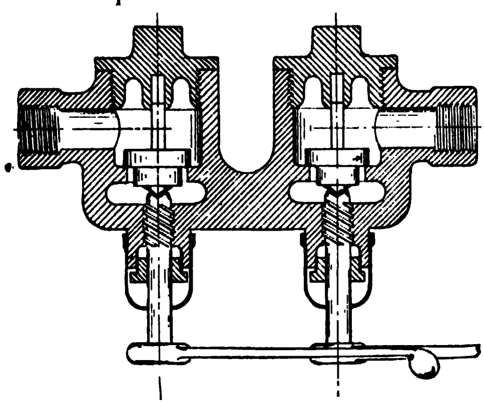
No. V (in preparation) External Plumbing.

Finally the main object of the Specifications is to encourage an approach towards uniformity in the subjects with which they deal, and to act as codes of reference in the working out of the details of plumbing. —*H. Blackman, B.Sc.*

See Anti-Siphon Pipe; Drains (Plate 4); Institute of Plumbers; One-Pipe System; Soil and Waste Pipe, *etc.*

MIXING VALVES. Valves used to mix hot and cold water so that the water delivered to a fitting is at any desired temperature. Occasionally steam is mixed with the cold water to warm it.

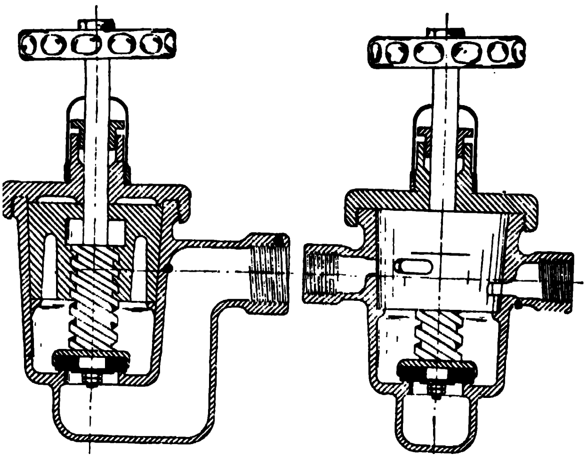
Mixing valves must have three connexions: two inlets for the hot and cold liquids and one outlet for the resulting mixture. The simplest type, therefore, consists of a metal chamber with two inlets, each controlled by a valve, the outlet being uncontrolled. By opening the valves as required, any desired proportions of hot and cold water may be obtained. Such a valve has the disadvantage that the user may be scalded if the hot valve is opened first. To avoid this use a



MIXING VALVES. Fig. 1. Valve (horizontal section) with separate levers to open hot and cold inlets, but in which hot cannot be opened first.

mixing valve (Fig. 1) in which the hot valve cannot be opened first, nor opened to a much greater extent than the cold valve.

Single-Control Taps. The valves so far mentioned have the disadvantage that two controls are necessary and these controls are to an extent interdependent. As one control is opened it not only increases its own flow but reduces that from the other. To overcome this defect, single-control mixing taps are now almost universal for private use. One method by which this effect may be obtained is shown in Fig. 2. Cold water enters at the bottom and hot at the top. The mixing valve itself is the hollow plug, which includes two slots. When the plug is turned by means of the handle one slot uncovers the cold water opening; as the handle is turned further the second slot uncovers the hot water inlet, and with still further turning the first slot is moved beyond the



MIXING VALVE. Fig. 2. Valve having single-control mixing tap: vertical sections taken at right angles to one another.

cold water opening, so closing the latter. The mixed water flows past the jumper to the outlet. The jumper is lifted from its seat by the first movement of the handle. Some valves incorporate the plug only.

It will be evident that operation of the handle produces first cold water, then tepid, and finally hot. Such valves are often termed "anti-scalding," since it is impossible to have hot water flow at the beginning of the handle operation. An additional refinement which completely prevents scalding is the fitting of a thermostatic control. In this case, if the water exceeds a set temperature, the valve outlet is closed by means of a bellows containing a heat-sensitive fluid. The bellows is contained in the body of the valve.

It is particularly important with single-control mixing valves to have hot and cold water at equal pressure; otherwise there is a tendency for creeping to take place round the plug shown in Fig. 2, so that hot water enters the cold water system and vice versa. Also, when the valve is operated, if there is a great difference in water pressures that at the lower pressure will be held by the water at the higher pressure, so that the low pressure water cannot flow. If, for example, the hot water is at the higher pressure, when its inlet is uncovered the cold water flow will almost stop, resulting in a considerable and rather sudden rise in the temperature of the issuing water.—*L. C. C. Rayner, A.I.E.C.*

See Bath; Bidet; Lavatory Basin; Taps.

MODEL BY-LAWS: MINISTRY OF LOCAL GOVERNMENT

By W. T. Creswell, K.C., Formerly Vice-Pres. R.San.I. and K. Miller Jones, M.A., LL.B.

Summarizing the most important provisions of the By-Laws and drawing attention to points that especially concern the Plumber and Sanitary Engineer. Many of the subjects named in the sections are dealt with elsewhere in this work under their own headings, both legal and practical notes there being given.

The following model series of by-laws which (among others) have been issued by the Ministry of Local Government and Planning affect sanitary administration. The more important are quoted. Technical details concerning specific fittings and requirements appear under many headings such as Ball Valve; Baths; Factories; Water Closet; Urinal.

Series III. **Common Lodging Houses.** (Made under Section 240 of the Public Health Act, 1936.)

By By-law 5, a keeper of a common lodging house must maintain in efficient order and in wholesome condition (*a*) the structure of every water closet; (*b*) the apparatus of such, and every drain or means of drainage with which it may communicate; (*c*) every earth closet or privy, etc.; and (*d*) all apparatus provided or used in connexion with the latter.

Series IV. **Buildings.** The following matters are of great importance to the sanitary engineer.

Water Closets must have a pan, basin, or other receptacle of non-absorbent material and a flushing apparatus that will secure the prompt and effectual flushing and cleansing of the pan. Only the flushing apparatus may be connected with a water supply or distributing pipe. No container must be fitted under the pan. "D" traps are prohibited on sanitary grounds. A water closet discharging into a soil pipe which receives the discharge from another w.c. or from a bath, sink, bidet or lavatory basin must have its trap ventilated by a 2-in. pipe,

3 inches and not more than 12 inches from the highest part of the trap, with an open end as high as the top of the soil pipe, or carried into the soil pipe itself 3 ft. above the highest connexion to that pipe.' (By-law 110).

Urinals. A urinal in a building with a water supply must have a basin, stall, trough, etc., of non-absorbent material, with an efficient grating to its outlet. Every urinal must have a suitable and effective flushing apparatus, and only the flushing apparatus itself must be connected with a water supply or distributing pipe.

A ventilating pipe must be provided to the trap of every urinal which can be entered only from within a building, and which discharges into a soil pipe which receives also the discharge from another urinal or w.c., bath, sink, etc. This pipe must comply with the dimensions given for a similar pipe in connexion with a w.c. (*see above*). (By-law 111.)

Water Tanks and Cisterns. A tank or cistern for storage of rainwater for human consumption must have a minimum capacity of 1,500 gallons. It must be provided with an overflow pipe, and the draw-off pipe must be 3 in. above the bottom. If wholly above ground level it must have a proper cover. If wholly or partly below, it must be constructed of brick, concrete or other suitable material made impervious and all pipes must have watertight joints. If the tank or cistern has a fixed cover, this must have an iron manhole cover, and means of ventilation. (By-law 118.)

Flue Pipes for Geysers. These must have a diameter equal to that of the flue spigot at the top of the geyser. The pipe must have a baffler, and discharge the fumes either into a chimney not communicating with any other room, or into the open air. If both are impossible, the discharge must be into a space, freely ventilated, below the roof. No geyser must be fitted into a room without a window that can be opened. (By-Law 121.)

SERIES XIII. **For Securing the Improvement of Housing Conditions.** (Section 6 of the Housing Act, 1936). Among other things, every owner of a house occupied or suitable for occupation by the working classes, must provide closet accommodation, a supply of water for domestic use, and accommodation for washing clothes. He must also keep in good repair all means of drainage, and every closet, sink, and bath, and provide and maintain in connexion with every tap from which water may be drawn efficient means for carrying off waste water. He must also provide every closet with efficient means of ventilation directly into the external air and, if the closet is not directly entered from the external air, provide a window of not less than 2 ft. super opening into the open air.

SERIES XIII B made under the same section relates to houses of a similar type which are let in lodgings or occupied by members of more than one family. In addition closet accommodation and supply of water must, where necessary, be provided for every family and every part of the house occupied as a separate dwelling.

SERIES XVII. **Tents, Vans, Sheds, and Similar Structures Used for Human Habitation.** (Public Health Act, 1936, Section 268).

The occupier of a tent, etc., must, when the structure is used for human occupation, maintain in good order, and in a reasonably clean and wholesome condition, any privy accommodation for which he is responsible. The occupier of any land on which he allows any tent, van, etc., used for human habitation to be erected, brought or used. must supply sufficient water, and, if a nuisance is likely to arise from the want of it, sufficient privy accommodation and means for the disposal of waste water.

SERIES XXI. **For Preventing the Waste, Undue Consumption, Misuse or Contamination of Water.** (Made under the Water Act, 1945, Section 17).

Under the interpretation part of the Series is an important definition of "corrosion-resisting alloy." It means an alloy which is highly resistant to corrosion by the water supplied, and which has a tensile strength of not less than eleven tons per sq. in. of sectional area.

Pipes (By-laws 7 to 19). Lead pipes must conform to British Standards specifications (7); and joints must be plumber's or equally suitable (9). Cast-iron and copper pipes must also conform to the above-mentioned standards (11, 13), while pipes of other materials must be of sufficient strength for working conditions. Wrought iron or steel pipes must be protected (12), and underground pipes (not beneath a building) must be 2 ft. 6 in. from the surface (18).

Stop Taps. Supply pipes must have stop taps placed between the main and

nearest point at which water can be drawn from the supply pipe, at a convenient and accessible position (22, 23). Underground stop taps must be adequately protected.

Taps and Valves. Every tap must have a pressure resistance of 300 lb. to the sq. in. (25), and every valve, spindle and other internal part and, where the nominal size of the tap does not exceed 2 inches, the body thereof must be made of a corrosion-resisting alloy (25).

Ball Valves. The Portsmouth type must in general conform to B.S. 1212 (1946). Those not of the Portsmouth pattern must, if for high pressure, close against a test pressure of 200 lb. per sq. in. For medium pressure and for low pressure the pressures are 100 lb. and 40 lb. per sq. in. respectively (26). When fixed, the size of the orifice, the float, and the length of the lever arm must be so adjusted that, with at least half the volume of the float above water level, the valve is watertight against the highest pressure it is required to sustain (26). No part of the ball valve body must be submerged at overflowing point. If a pipe discharges water from a ball valve into a cistern at a point below overflowing level, an air hole must be made in the pipe above that level to prevent siphonage back through the valve (28).

Cisterns. Storage cisterns must be watertight and constructed as prescribed (33). Storage cisterns must be properly covered (35), and must hold not less than 25 gallons (37) ; they must, generally, not be buried (40) or placed where liable to contamination (35).

Hot Water Apparatus if not supplied from a cold water feed system requires a tap, but this does not apply to gas heaters of the types stated (41).

Baths and Lavatory Basins. Inlets and outlets must have watertight plugs or other suitable apparatus (51).

Flushing Apparatus for Water Closets and Urinals must be provided (53). All pipes or fittings within a building must be accessible (21). Persons laying, etc., supply pipes must allow the council (or company) to fit, and have access to, an additional stop tap (By-law 22). Seven days' notice must be given by persons who propose to use water supplied otherwise than by meter for operating apparatus of the types specified or for hosepipes, and three days' notice must be given before fixing or altering (otherwise than by way of repair or renewal) any water fitting in connexion with any existing supply.

MONEL METAL. Certain unfamiliar alloys are now finding increasing uses in the plumbing and sanitary engineering trades. In particular, the alloys of nickel provide unusual properties in that not only do they combine high strength and high ductility, but they possess in addition exceptional resistance to corrosion by many liquids, especially salt water. Monel metal is composed of nickel and copper essentially, but minor impurities such as, iron, silicon, and magnesium may also be present. The following analysis is typical of Monel used for tubing in the plumbing and allied trades :

Copper	31·9 per cent
Nickel	67·1 ,,
Iron..	0·4 ,,
Silicon	0.1 ,,
Carbon	0·05 ,,

This alloy is therefore composed approximately of 70 per cent. nickel and 30 per cent. copper. Nickel and copper are often found associated in nature ; in Ontario, Canada, the nickel ores are such that when smelted an alloy containing about 70 per cent. nickel and 30 per cent. copper is obtained. To this alloy has been given the name Monel, but it will be clear that owing to slight variations in the ore minor fluctuations may be expected in the composition of the resulting alloy. These variations in composition are so small that appreciable differences in properties of Monel metal need not be feared.

When cast, Monel metal has a cored structure and is thus not uniform in composition ; analyses as ordinarily made do not reveal these differences in composition, which can only be observed by microscopic examination. This non-uniformity can be removed by annealing, so that since copper and nickel are completely soluble in one another the structure of the annealed metal is exactly similar to that of a pure metal. As such it is therefore far more resistant to corrosion than in the cast condition. Hence Monel metal tubes are frequently specified for conveying hot water—as, for instance, in the case of tubes for boilers where corrosive conditions exist.

Monel metal can be worked readily, can be forged hot and can be worked cold. It has exceptional mechanical properties which combine high strength with good ductility, and the strength of the alloy is of course greatly enhanced by drawing into wire form. Average values for the cast metal are 22 tons/sq. in. in tensile strength and 15 per cent. elongation; while after drawing into wire a tensile strength of 60 tons/sq. in. may be expected.

In the form of wire, Monel metal possesses also the valuable property of resilience and of high elastic limit, and hence is often adopted for valves of steam engines and for numerous similar applications depending upon its resistance to corrosion. Although the initial cost of Monel fittings is invariably higher, this disadvantage is completely offset by the greatly increased life obtained, so that cost should not be a deciding factor in considering this metal for any purpose for which it is specially suited.

Monel metal can be machined easily, will take a fine thread, but is stated to be more troublesome to machine when cast than after annealing. This is to be expected, since annealing brings about the removal of local non-uniformity. Emphasis must here be laid upon the fact that nickel alloys in general are susceptible to attack by gases containing sulphur, such as flue gases. The mechanical properties are considerably impaired and the ductility is very greatly reduced, so that in any form of heat-treatment given to Monel metal—whether it be for annealing, for forging, or for brazing or welding—fuels of low sulphur content must be used.

Monel metal may be readily soldered, brazed and welded, both to itself and to other non-ferrous alloys, but scrupulous cleanliness is essential to obtain good results.

As to uses, Monel metal is adopted in the plumbing and allied trades chiefly for components of hot-water systems, as tubes in condenser plants; for fittings and components of pumps; for nozzles and valve bodies, particularly where corrosive liquids such as salt water are to be conveyed.—*W. F. Chubb, Ph.D., B.Sc.*

See Alloy; Copper; Nickel.

MOTOR, ELECTRIC. A machine for converting electrical into mechanical energy, consisting essentially of a fixed and a rotating part, each capable of setting up a magnetic field; the interaction between the two fields causing a torque to be developed at the shaft of the machine. In heating and sanitary engineering and ventilating work they are employed for many purposes, as for accelerators, fans, pumps, etc.

Electric motors may be divided broadly into those that will operate only on Direct Current, those that will operate only on Alternating Current, and "universal" machines, or those that will operate on either.

Direct Current Machines. In the direct current machines the stationary part is known as the field system (or "field"). This consists of a cast-iron or steel yoke to which the magnetic pole or poles are fitted. In certain small machines for special purposes (for example, those used in certain types of wind-screen wiper), these poles may be permanent magnets, but otherwise it is more usual for them to be electro-magnets. In these last-named a solid iron core cast integral with the yoke, or a core consisting of thin sheets or laminations of magnet steel riveted together and fastened to the yoke by studs, is magnetized by a coil of insulated copper wire or strip fitted over it and carrying an electric current. The winding is known as the exciting coil or field winding.

The pole cores carry pole shoes for distributing the magnetic field (or flux). These shoes may be detachable, in which case the winding is placed over the core before the shoe is bolted in position; or they may be integral with the core, in which case the coil is slipped over the pole before it is bolted to the yoke. The direction of the winding is so arranged that the poles are alternately north and south. Small machines usually have the minimum number of poles: one north and one south.

The rotating portion is called the armature: this consists of a number of thin stampings of magnetic steel of such a shape that when pressed on to a steel shaft a number of slots are formed on the periphery, in which the armature coils are placed. In very simple machines these slots are absent and the winding lies on the surface. Most armature cores are also provided with ventilating channels parallel to the shaft, and larger machines

have radial ventilating ducts as well.

Also fitted on the armature shaft is the commutator. This consists of a number of copper segments insulated from one another by mica strips and arranged to form a cylindrical surface. The coils are connected to the commutator segments in a certain set order by sweating their ends to risers from the segments. Pressing on the commutator are one or more pairs of spring-loaded carbon brushes, whose function is to transfer current from the fixed to the movable portion; and, in conjunction with the commutator, to ensure that the current in the armature coils is in the right direction at all times.

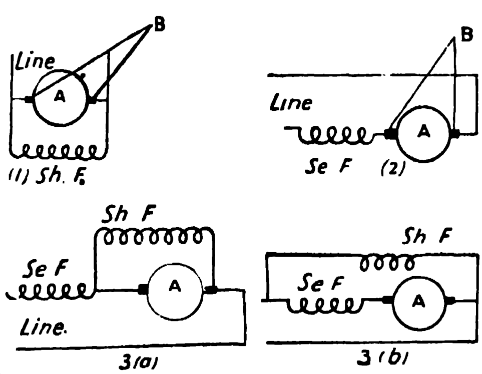
As a coil passes from the sphere of influence of one pole to the next it is necessary for the current in the coil to reverse its direction; this reversal takes place when the commutator segment to which the coil is connected passes under a brush. On larger machines this reversal would be accompanied by sparking at the brushes unless special precautions were taken. In the older types of machines the brushes were mounted on a "rocker," which enabled the position of the brushes to be changed with variations in the load, but the usual practice at the present time is to keep the brush position fixed and to fit in between the main poles smaller poles (known as interpoles), whose function is to suppress the tendency to sparking. These coils carry the same current as the armature. The armature shaft rotates in ball, roller or sleeve bearings.

Direct current machines are divided into three types (shunt, series, or compound), according to the manner in which the field winding is connected. In all these the windings on each pole are connected in series; this leaves two ends unconnected. In the ***shunt machine***, whose field windings consist of a large number of turns of fine wire, these ends are connected directly across the armature via the brushes and take the full line voltage. The field winding of the ***series machine*** consists of a relatively few turns of heavy gauge wire or strip, one end of which is connected to the armature connexion, and the other directly to the line; as the field is connected in series with the armature it carries the full line current. In the ***compound machine*** there are two distinct windings (a series winding and a shunt), and each pole carries two coils. Depending on the point of connexion of the shunt winding, the machine is known as a long or short shunt.

The shunt machine runs at practically constant speed at all loads; on a well-designed machine the speed falls only slightly with increase in load. The speed of the series machine, on the other hand, varies considerably with the load. When the load is heavy the speed is low, and vice versa. This class of machine has a good starting torque; that is to say, it is capable of starting against a heavy load (whereas the shunt machine is not). Consequently the series machine is used for traction purposes and for operating lifts. The compound machine has characteristics intermediate between the shunt and series types.

The resistance of the armature winding is very small, and if a motor is switched directly on to the line there is at first a very heavy rush of current. When the armature starts to rotate, a voltage is generated in it which opposes the applied voltage and consequently causes the armature current to fall to a normal value.

Fractional horse-power machines (and the usual run of machines used for domestic purposes are included in this class) may be switched directly on to the line, but larger machines must be connected through a starter. This puts a resistance in the armature circuit, which limits the current at the start. As the speed of the machine increases, the resistance is gradually cut out. The terminal connexions are usually clearly marked on the starter (L for line, F for field and A for armature). The connexions for a face plate starter for a shunt machine are shown in Fig. 2.

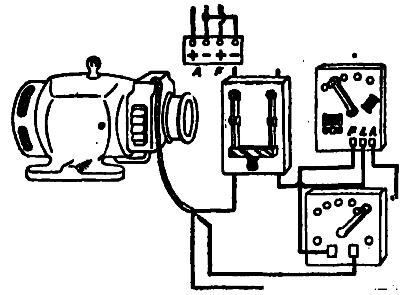


MOTOR, ELECTRIC. Fig. 1. Connexions of (1) D.C. shunt machine; (2) series machine; (3a) compound short shunt machine; (3b) compound long shunt. A, armature; B, brushes; Sh.F., shunt field; Se.F, series field.

Reversal of Rotation. The direction of rotation of a D.C. machine may be reversed by changing over the leads to the armature or to the field (but not both).

Speed Control : Shunt Machine. A resistance (field rheostat) is included in the field circuit ; increasing the resistance increases the speed.

Series Machine. A resistance (diverter resistance) is placed in parallel with the field circuit. Reducing this resistance by reducing the current in the field-circuit, causes an increase in speed.



MOTOR, ELECTRIC. Fig. 2. Connexions to face plate starter for a D.C. shunt machine, with terminals marked : F, field coil ; A, armature ; L, line. The series-parallel circuit includes motor, voltmeter and ammeter.

Alternating Current Motors. There are far more types of motors in this class than in the former one. Some of the more important types will be briefly described. In A.C. motors the fixed portion is called the stator, the rotating portion being termed the rotor.

Synchronous Motor. This type runs at one fixed speed, the synchronous speed, the value of which is given by the formula

R.P.Ms. $= \frac{60f}{P}$ where f = the frequency of the supply and P = the number of pairs of poles.

Except in the case of a group of ultra-fractional motors of a special type, synchronous motors must be run up to synchronous speed by auxiliary means, *e.g.* by a D.C. shunt machine or by an induction motor. The special class of synchronous machine referred to above is used for self-starting electric clocks and similar purposes. There are several different designs ; in two of the most important, the machine is first run up to synchronous speed as an induction motor of the shaded pole type.

Induction Motor. This is so called because there is no external supply to the rotor, and the stator field induces the field in the rotor. Induction motors are divided into squirrel-cage rotor (S.C.R.) and wound rotor types. In the former, insulated copper or aluminium conductors are laid in slots in the rotor (which is somewhat similar to the armature of a D.C. machine), and the ends of the conductors are welded to two metal rings so that the complete winding is short-circuited. This makes an extremely robust construction, and the rotor can develop no faults except mechanical ones. The wound rotor carries three separate windings connected to slip-rings on the rotor shaft, which can be connected via brushes to a three-phase starting resistance.

The wound rotor type has better starting characteristics than the squirrel-cage type, but the simplicity of the latter commends it for many purposes. In both types the stator consists of a number of laminations fastened to the yoke, having slots in which the stator winding is placed. Three and two-phase machines have as many windings as phases, but a single-phase machine has two, not necessarily identical, unless it is not required to be self-starting, then it has only one.

It is a characteristic of polyphase motors that the supply of current to the stator sets up a rotating magnetic field which drags the motor round with it, but at a slightly lower speed. For this reason two- or three-phase induction motors are self-starting. In a normal single-phase machine the stator does not provide a rotating field and the machine is not self-starting. The direction of the rotation of a polyphase induction motor can be reversed by changing over any two of the leads to the stator. Small single-phase machines can be started by hand, and the direction of rotation depends on the direction in which the rotor is first revolved. Small machines may be switched directly on to line, but larger machines must have starters, which may be of the star-delta or tapped resistance, or the auto-transformer type.

Single-Phase Machines. Various expedients have been tried in order to make single-phase motors self-starting. The split-phase type of machine has two windings, one of which is fed through a resistance and the other through a condenser. This has the effect of producing a two-phase field from a single-phase supply.

In the capacitor-start induction motor a condenser is used for operating the starting winding ; this winding and condenser are

cut out of circuit by a centrifugal switch when the machine has run up to speed. It then continues to operate as an induction motor. The capacitor-start-capacitor-run motor is similar except that a condenser is included in the circuit even after the machine has run up to speed. This has a slightly better efficiency than the previous type. It is suitable for reversing if the machine is first allowed to stop.

A.C. Commutator Motors. Many different types of A.C. commutator motors are being developed, but it is not necessary to describe them here. The universal machine is an A.C. commutator of the series type similar in many respects to its D.C. counterpart (shunt machines are not suitable for A.C.). The A.C. variety is larger than the corresponding rating of D.C. machine, and added precautions have to be taken to laminate the whole of the magnetic circuit thoroughly. Special care has also to be taken to counteract sparking at the brushes. Small motors of this type, which may be switched directly on to the supply, are used for vacuum cleaners, electric washers, and similar domestic purposes. They have also been used for refrigerators, but as the commutator may cause wireless interference an induction motor of the capacitor type is better.—*R. A. Baynton, B.Sc., A.M.I.E.E.*

MUNTZ METAL. The alloys of copper and zinc known as the brasses reach their maximum strength with a composition of 60 per cent. copper and 40 per cent. zinc. This alloy is widely used under various trade names, the most popular being muntz metal. Although stronger than either ordinary common brass or those brasses capable of being cold worked, it is less ductile and can in fact only be worked in a heated condition. It is thus used after drop forging or stamping for plumbing fittings and fixtures, such as brackets, and is also for high tensile strength bolts. The forging temperature is about 600° C., or a just visible red heat; and when hot worked (as by forging) muntz metal has a tensile strength of about 40 tons per sq. in. with an elongation of about 20%. It can be machined easily. Like all copper-zinc alloys over 55% copper it is liable to corrosion in contact with sea water, natural fresh waters and certain aqueous solutions due to dezincification. It is very resistant to sulphide solutions and the atmosphere. *See* Alloy; Brass.

NATIONAL INSURANCE ACT, 1946. In this Act, which came into operation on July 5, 1948, all social services which involved cash payments to insured persons, and which previously operated under the National Insurance Acts, the Unemployment Insurance Act, and the Widows, Orphans and Old Age Pensions Act, are dealt with under one system of administration.

The Act is based, with some modifications, on a report of a committee under the chairmanship of Sir William Beveridge, published in 1942, and on a Government White Paper published in 1944.

Contributions are made to a National Insurance Fund by insured persons, employers, and the State, and all moneys in respect of health services for insured persons are paid out of this fund.

Persons who must be insured persons under the Act comprise all who are between the school-leaving age of 15 years and the pensionable ages of 65 years for men and 60 years for women, without distinction between the sexes or between persons who are employed, self-employed, or non-employed. All persons employed under any contract of service or apprenticeship are " insurable " irrespective of the work they do or their income.

Provision is made in the Act for payment to insured persons in the following circumstances: benefits to widows; for unemployment; in case of sickness; for maternity; for retirement pensions; allowances to guardians of orphans; and a death grant.

Administration of the scheme is carried out by the Ministry of National Insurance, who have set up a large number of local offices for the administration of the provisions of the Act.

Industrial injuries are not covered by this Act, but compensation is provided for in these cases by the National Insurance (Industrial Injuries) Act, 1946 (*which see*) by replacing the Workmen's Compensation Acts. Medical benefit is, however, provided under the National Health Act, 1946.

NATIONAL INSURANCE (INDUSTRIAL INJURIES) ACT, 1946. This is a most important Act affecting workmen and makes revolutionary changes in legislation affecting compensation for injuries.

The Workmen's Compensation Acts were consolidated in the Act of 1925, but

there were ten subsequent amending Acts up to 1945. Now, the whole is covered by the new Act with the radical difference that compensation is paid out of a National Fund and not by the employer, and is in effect a compulsory insurance scheme.

The Act is administered by the Ministry of National Insurance ; contributions are paid into an Industrial Injuries Fund by employers, employees, and the State; and out of this fund benefits are paid in respect of personal injury caused by accident arising out of and in the course of a person's employment, and disabilities caused by the nature of a person's employment and purposes connected therewith.

With certain specified exceptions all persons employed under any contract of service or apprenticeship are in " insurable employment," irrespective of the work they do or the income they receive. Apart from excepted persons, there are also excepted employments.

Contributions. Every person in insurable employment, and every employer of such a person, unless specifically exempted, is liable to pay equal weekly contributions on the following scale :

Men over 18 years	4d.	Employer	4d.
Women over 18 years	3d.	Employer	3d.
Boys under 18 years	2½d.	Employer	2½d.
Girls under 18 years	2d.	Employer	2d.

Contributions to the fund must also be made out of moneys provided by Parliament, estimated to be equal to one-fifth of the aggregate amount paid as above.

An employer must, in the first instance, pay both his own and his employees' contribution ; the latter may be recovered by deductions from wages, but it is illegal for the employer to deduct the amount of his own contribution in the same way.

Benefits. Under this Act benefits are related to the degree of disability suffered and not to loss of earning power. It is the purpose of the Act to ensure that wholly or partially disabled persons actually receive a payment corresponding to their needs.

There are three types of basic benefit :

(1) Industrial Injury Benefit, referred to as " injury benefit."
(2) Industrial Disablement Benefit, referred to as " disablement benefit."
(3) Industrial Death Benefit, referred to as " death benefit."

Injury Benefit is payable in respect of incapacity to work, and is intended to cover the initial period of incapacity up to 156 days, excluding Sundays, from the day the injury was sustained. If the incapacity extends beyond that period the benefit is changed to disablement benefit.

No injury benefit is payable in respect of the first three days unless the insured person is incapable of work on not less than twelve days, which need not be consecutive.

Disablement Benefit is payable where the insured person is : (*a*) still incapable of work after the injury benefit period ; and (*b*) after he is capable of returning to work but continues to suffer loss of mental or physical faculty to a specified degree. The term " loss of physical faculty " includes disfigurement.

Death Benefit is payable where the injury results in the death of the insured person, and the persons who may receive the benefit are the deceased's widow or widower, a person whose family includes a child or children of the deceased ; a parent, relative, or woman having the care of his children, providing they were maintained by the deceased.

There are a number of exceptions and qualifications to be complied with before any person is held to be entitled to receive death benefit.

In addition to the above basic benefits certain other benefits may also be payable in non-fatal cases.

If a person is likely to remain permanently incapable of work through loss of faculty he may have an " unemployability supplement " added to his disability pension for a given period. If he is incapable of following his previous employment or some employment of an equivalent standard, his disability pension may be increased for any period in respect of which he is not eligible for the unemployability supplement.

A disability pension may be increased in respect of constant medical attendance, where free treatment at a hospital or institution is not being received, but the original pension is not reduced while the insured person is in such hospital or institution.

Increases in benefits may be made in respect of dependants of the insured person, under given circumstances.

Determination of Questions. In the first instance, all claims to benefit must be made to Insurance Inspectors appointed under the Act, but there is a right of appeal

against their decisions to a local Appeals Tribunal, consisting of equal representation of employers and insured persons with a chairman appointed by the Minister, and in proper circumstances the appeal may be taken further, to the Industrial Injuries Commissioner appointed by the Crown.

The Insurance Inspector may consider that a "special question" arises as follows:

Special Questions may be whether a person was in insurable employment within the meaning of the Act ; whether there is any exemption from payment of contributions ; who is liable to pay contributions as an employer ; the rate of payment of contributions ; whether any increase of disablement pension is allowable, and ; what limitations there may be on payment of death benefit. The above special questions are to be determined by the Minister.

There are other special questions relating to : loss of faculty ; the degree of disablement resulting therefrom, and ; the period to be taken into account. These latter questions may be determined by a Medical Board or Medical Appeal Tribunal.

A considerable change from the provisions of the Workmen's Compensation Acts is that benefits now cover injuries received by an insured person who at the time of the accident may have been contravening statutory or other regulations applicable to his employment.

Benefits may also be paid if the person is injured when travelling to or from work in transport provided by the employer and with his express or implied permission.

If, while in or about his employer's premises, an insured person is injured in an attempt to rescue or protect other persons, or to avert or minimise serious damage to property, in an actual or supposed emergency, he may be eligible for benefit.

The above is a simplified account of the main outline of the effect of the Act upon employers and employees. The actual provisions are more complicated, and the Act also provides for the making of Regulations on a number of points. It will be essential, therefore, to refer to local Insurance Inspectors in all cases of doubt.

It must be emphasised that this Act entirely supersedes from July 5, 1948, the whole series of Workmen's Compensation Acts. As stated under Employers' Liability (*which see*) there still remain certain minor considerations of insurance for the employer.—*B.G.Phillips, F.I.A.S., M.R.San.I.*

NICKEL. The general properties of nickel which have made it prominent as a material for plumbing fixtures and fittings are its relative hardness, its strength and toughness, and the fact also that it acquires a surface of high decorative value when polished. Nickel also possesses good corrosion resisting properties, but is inferior to chromium (*see* Chromium Plating), since as a deposit it is somewhat porous.

In plumbing and house decorating nickel is mainly used in the form of a protective coating on base metals such as brass, the bright metal being deposited in order to withstand the corrosive action of moist atmospheres. Unprotected fittings, and particularly those directly exposed outdoors to weathering influences, rapidly tarnish and this action ultimately leads to surface pitting and loss of decorative value. This trouble is, however, overcome to a large extent by nickel-plating the articles so exposed ; this electro-deposition usually involves a preliminary coating of copper in order to increase the power of adhesion of the nickel, which is later applied by electrolytic methods.

Nickel deposits, however, tarnish fairly rapidly in moist atmospheres as compared with chromium deposits, and hence such fittings have to be polished frequently, whereas chromium deposits need merely be washed at intervals in order to restore their surface lustre and decorative value. For this reason nickel-plated fittings, though less expensive than chromium-plated fittings, are not so satisfactory. (*See under* Chromium Plating for discussion of comparative virtues of the two metals.)

Nickel is now being used as a cladding material for steels, a layer of pure nickel being bonded to the steel during manufacture. The composite plate is formed by pressure-welding the nickel to the steel slab in a rolling mill at a temperature exceeding 1,000°C. Metallic arc welding is usually adopted when nickel-clad steel is used for pressure vessels and the like.

Defects. The chief fault with the cheaper grades of nickel-plated fittings is their tendency in time to peel. This may arise from two main causes : in the first place, improper conditions of electro-deposition cause the production of a relatively non-adherent nickel deposit ; secondly, the omission of the preliminary copper deposit (which is often done to

reduce production costs) and the direct plating of nickel, especially on iron and steel parts, results in lack of adhesion and the nickel so deposited invariably peels off later in use. There are also other reasons for the peeling, but these are of a purely metallurgical character.

A further disadvantage of nickel is that it is considerably softer and less resistant to wear than chromium.

Alloys. Nickel is employed as an addition to certain alloys used in making household fittings, such as taps for the bathroom. It is often added in small amounts to brass and gunmetal to provide a stronger and tougher alloy. Alloys containing nickel are generally more resistant to corrosive influences, and thus many of the alloys used in water systems contain measurable quantities of nickel. It is also a major constituent in nickel or German silver (*see* Alloy) and Monel metal (*which see*).—*W. F. Chubb, Ph.D., B.Sc.*

NOISE. Annoyance caused by undue noise in plumbing systems and its prevention, particularly in flats, is considered in Building Study No. 4, "Plumbing." *See* Suppt., Vol. 3.

NOTICE OF WORKS. For the purpose of ensuring that drainage and plumbing work shall be carried out in a satisfactory manner, Acts of Parliament empowered the making of By-laws with this object in view. Sanitation within the County area of London is governed by revised By-laws made in 1934 by the London County Council, under Section 202 of the Metropolis Management Act, 1855.

It is important to note that under "Interpretation of Terms" "drainage work" means "any pipe, drain or other means of communicating with sewers and any trap or apparatus connected therewith." This definition covers a very wide range and includes all sanitary fitments, together with all pipes connected thereto. The definition of "builder" means "for the purpose of the By-law No. 14 relating to the deposit of plans . . . the builder, contractor or person intending actually to execute such work, but does not include a workman in the employ . . .of such . . .person." The plumbing sub-contractor on a large job, or a plumber with a small jobbing business, is, therefore, held responsible for notifying the local authority of proposed alteration, additions or repair to "drainage work."

By-Laws. The following is a summary:

Alteration, reconstruction and repair. No alteration, partial or entire reconstruction, or repair of any drainage work . . . shall be made that . . . will not be in conformity with these by-laws.

Plans and notices of drainage work. Deposit of plans, etc., of drainage work. Every person about to construct, reconstruct, or alter any drainage work shall deposit . . . in duplicate with the sanitary authority . . . such plans, sections and block plan . . . made on cloth or linen, and such detailed description and particulars . . . as may be necessary for the purpose of enabling such authority to ascertain whether such construction . . . will be in accordance with . . . the by-laws. The plans, sections, detailed description . . . shall be signed by, or on behalf of, such person, and deposited seven days . . . before such construction, . . . and in the case where such construction is in connexion with a building to be erected, seven days . . . before commencing the erection of the building.

Drawings and Particulars. The details of the plans, sections, and particulars required are as follows:

The scale of drawings, plans and sections shall be not less than one inch to every sixteen feet. The position of all soil and waste water fitments must be indicated. The fall of every drain, and the position and size of every drain, means of access (usually manholes), trap, gully, soil pipe, waste pipe, ventilating pipe and rainwater pipe. The height of chimney or window within a distance of twenty feet from a soil pipe or ventilating pipe. The level of the lowest floor in relation to the street level. The level of any yard, area, ground or open space in connexion with such building. The scale to which such plans are drawn. The block plan scale shall not be less than 1 in. to every 88ft., and shall show the premises in which the proposed work is to be carried out, and also adjoining premises. The names of the streets in the immediate vicinity should be shown so as to indicate its relative position in that part of the district. Although the block plan should show proposed and existing drains, they are usually shown on the larger scale plan.

The particulars required should describe the general mode of construction, such as the material for drains, soil and waste pipes and their joints. Notice, in writing, that the work is about to commence must be given 24 hours before the work is started. In urgent cases, notice in writing shall be given that work must be commenced forthwith, and plans shall be deposited within 15 days.

No plans need be deposited in the case of a repair which does not involve alteration of any drainage work.

Penalty. The penalty to which a builder is liable in not giving notice or despositing plans, etc., is Two Pounds for each offence, and a continuing penalty of Twenty Shillings per day after written notice of the offence is given.

The Ministry of Health Model By-Laws are somewhat similar, while the penalty is extended to Five Pounds on conviction and Forty Shillings per day as a continuing penalty.—*F. C. Cook, M.R.San.I., R.P.* *See* London County Council By-Laws; Model By-Laws.

NUISANCE. A nuisance has been defined as anything which worketh hurt, inconvenience or damage to any person. Nuisances may be broadly divided into:

(*a*) Acts or omissions which obstruct or cause inconvenience or damage to the public in the exercise of their rights, as when A blocks up a public highway;

(*b*) Acts or omissions which are treated as nuisances by Statute, as when A permits any pond, pool, ditch, or gutter to become a nuisance; and

(*c*) Acts or omissions connected with the user or occupation of land, and which cause damage to another user or occupier of land, as where A carries on an offensive trade next door to B.

A person cannot bring an action for damages for a public nuisance unless it has inflicted some peculiar damage to himself. Nor can he sue a public authority for nonfeasance, that is, the omission of something the local authority should have done. He can, however, sue for misfeasance—that is, the doing of a lawful act by the local authority negligently, as, for instance, if a trench were dug in a road and he were injured thereby.

A person injured by a nuisance may bring an action against the wrong-doer—that is, the one who causes it—for damages for injury alone, or for a claim for an injunction as well. The damages payable must be such as will compensate for the loss sustained as a result of the wrongful act. An injunction will only be granted to restrain the continuance of a nuisance when the injury done by the nuisance is substantial, or when it is a continuing or recurring one. It will not be granted for anything which is trivial or temporary.

In certain circumstances it is possible for the person aggrieved to abate the nuisance himself, but in general it is unwise for him to take this course when he has a remedy at law.

Statutory Nuisances. In general, under Public Health Acts, local authorities must discharge their functions so as not to create a nuisance, and they must inspect their district in order to detect any nuisances. Statutory nuisances may be dealt with summarily, such as:

(*a*) Premises which are in such a state as to be prejudicial to health or a nuisance;

(*b*) A factory, workshop or workplace which is not sufficiently ventilated or kept clean or not kept free from noxious effluvia, or which is so overcrowded while work is carried on as to be prejudicial to the health of those employed therein.

If a local authority is satisfied of the existence of a statutory nuisance it must serve an "abatement notice." It is served on the owner of the premises if the nuisance arises from any defect of a structural character; and if the person causing the nuisance cannot be found, the local authority may themselves do what they consider necessary to abate the nuisance and to prevent a recurrence of it.

A court of summary jurisdiction may make an order to abate if an "abatement notice" is disregarded, and prohibit a recurrence of the nuisance; and if the person who is responsible for the nuisance, or the owner or occupier of the premises cannot be found, the order may be addressed to, and executed by the local authority, and they can recover the cost of abating the nuisance. The local authority can take the case to the High Court if it is thought summary proceedings will prove inadequate.

Any person aggrieved by a statutory nuisance may complain to a Justice of the Peace.

Smoke Nuisances. An installation for the combustion of fuel used in any manufacturing or trade process, or for working engines by steam and which does not practically prevent the emission of smoke, and any chimney (not being the chimney of a private house) emitting smoke in such quantity as to be a nuisance, are statutory nuisances and a local authority may make by-laws regulating the emission of smoke—that is, as to colour, density or content. Also building by-laws may require the provision in new buildings other than private houses of arrangements for heating or cooking so as to prevent or reduce the emission of smoke.—*W. T. Creswell, K.C., Vice-Pres., R.San.I.*

OFFICE ROUTINE AND BUSINESS ORGANIZATION

By R. A. Price, A.C.I.S.

This article is concerned with the management of office work and the methods and appliances best suited to the needs of the Plumber and Heating Engineer. For the executive aspect of business management, see under Business Methods. Reference should also be made to Accounts; Audit; Balance Sheet; Book-keeping and Finance.

In all cases where the staff consists of two or more members, the work should be so arranged that there is (*a*) division of responsibility and (*b*) internal check.

Division of responsibility means that each employee is allocated definite duties, to be performed only by that employee. If the work is left to be done by anybody available, omissions and errors may occur for which no person in particular can be held responsible.

Internal Check is even more important. The object is so to distribute duties that one clerk acts as a check against another; apart from collusion, fraud would then be difficult. For instance, rendering invoices, posting ledgers, checking inward invoices and preparing the wages book should be done by clerk A, while clerk B should confine his attention to collecting and paying accounts, entering up the cash book and paying wages.

Efficiency and Economy. These must be the keynote of office work. They are best achieved by carefully planning each day's activities. For the numerous papers and other matters requiring daily attention, use a series of appropriately labelled folders: e.g. (*a*) Letters ready for reply; (*b*) Enquiries to be made; (*c*) Invoices to be checked; (*d*) Insurances; (*e*) Advertising, etc. A classification of work to be done leads to efficiency and speed, while attempting to deal with a heterogeneous heap of papers causes bewilderment and mistakes. This collection of folders has aptly been termed a "work organizer," and there is no doubt that a few minutes spent in the classification of details make the remainder of the day comparatively easy.

Loose Leaf Ledger. Although the initial cost is greater than that of the older "bound" ledger, a loose leaf ledger affords the advantages of permanence, ease of reference, and elasticity. It never becomes full. It never needs re-writing. As and when leaves are filled they are transferred to a separate binder and replaced. It is not encumbered with "dead" accounts or full pages, for these are removed periodically. The leaves may be arranged alphabetically, thus rendering the book self-indexing. With the bound ledger, each page is numbered and a separate index is necessary.

The business never becomes too big for the ledger, which is capable of expanding with the growth of transactions. The same alphabetical sequence may be preserved even where the ledger needs to be accommodated in more than one binder.

The benefits of the loose leaf ledger are most felt when applied to debtors, whose accounts are usually numerous.

Stationery. When designing stationery, have the space for the recipient's name and address in a position which, when the document is folded, will correspond with the "window" of the envelope. Time saved by the use of window envelopes more than covers their small extra cost, while mistakes in addressing or inserting the wrong enclosure are avoided.

If invoices and other forms or headings are normally to be addressed or filled in on a typewriter, see that the printer spaces his blank lines to correspond with the standard line-spacing of the typewriter. Much time and trouble will thus be saved to the clerk.

Addressing Machine and Duplicating Apparatus. In any business which has even a moderate number of regular customers, the addressing machine is a useful labour-saving and mistake-preventing device. The idea is to prepare a template for each addressee. The templates are put into the magazine of the machine, and envelopes or other stationery are automatically addressed. The machine is of great value for publicity work. In the article on Advertising (*which see*) it is suggested that an index of present and prospective customers be kept. Prepare a template for each entry in that index, and whenever it is desired to circularize

"prospects," the necessary envelopes may be prepared in a very short time (about 1,000 per hour by the hand-operated machine, and 3,000 per hour electrically).

Duplicating apparatus is another useful adjunct to publicity work, or indeed wherever a circular or repeat letter is required. A template or stencil is either typewritten or handwritten, and placed in the duplicator. Paper is then fed into the machine, and numerous reproductions of the original are obtainable. There are two types of apparatus: (*a*) flat, and (*b*) rotary. The flat machine is cheap, and produces work of a quality equal to the more expensive rotary model. The advantages of the latter are greater speed and a larger number of copies from one stencil. In addition to producing circular letters and advertising matter, the machine may be used for duplicating "form letters"—*e.g.* acknowledgments of orders and remittances, or letters requesting payment of overdue accounts. By preparing a stock of such stationery, much time ordinarily occupied in typing individual letters of a stereotyped nature will be saved.

Filing Systems. The lack of a satisfactory system for the preservation of correspondence is responsible for a loss of time and money out of all proportion to the cost of installation.

The requirements of a system are: (*a*) effective preservation of documents; (*b*) rapid production of any paper required; (*c*) minimum of time to work; (*d*) economical in cost and space occupied; and (*e*) it must be foolproof—a document which is mis-filed is as good as lost.

The main reasons for the preservation of documents are that they may be used as evidence in court in case of dispute, and that they constitute a permanent record of transactions with customers.

The *vertical folder system* is beyond doubt the one which will satisfy the above requirements. Its cost is saved within a short time of installation; and whatever size the business may ultimately become, the same outfit will still meet all demands, for the system may be expanded indefinitely. The apparatus consists of (*a*) a collection of Manila folders; (*b*) guide cards; (*c*) a cabinet to hold folders and guides; and (*d*) a card index.

Normally, one folder is used for each correspondent. A folder contains, in strict date order, original letters received and copies of replies. Copies of all letters sent must be made. Copying machines are obtainable, but the cheapest method (and one used by the largest concerns) is to produce copies by carbon paper. Carbon copies may be made even where a typewriter is not available, by using a hard (manifold) pen nib. The folders are numbered consecutively, and placed in the cabinet in numerical order. The guide cards are inserted at intervals of 10 folders, and projecting tabs on the guides bearing the numbers 10, 20, 30, etc., enable rapid selection of any folder to be made. An index is necessary to locate folders, and for this purpose the card index cannot be excelled. It is suggested elsewhere that a card index of customers be maintained for purposes of publicity, etc., and this same index will serve for the filing system.

The vertical system may be operated without a card index, and in the case of the small business, where much of the clerical work is often performed by the head himself, this method may be preferred.

The apparatus necessary is that specified under (*a*) to (*c*) above for the numerical classification. Instead, however, of being arranged in number sequence, the folders should be in alphabetical order. A very small business, with a proportionately small volume of correspondence, would manage quite well with one folder for each letter of the alphabet. The correspondence in each folder should be placed in alphabetical order, for easy reference. For example, take folder B, which contains all letters the surname of which begins with B. Correspondence with persons or firms of the following names would be filed in the order here given: Baxter & Co., Wm. Bayley, Jos. Bennett, Robt. Beswick, Birtles Ltd., Thos. Bleasedale, Henry Boardman, Frank Brayshaw, Alfd. Burgess. In other words, file in a similar order to that found, say, in a telephone directory.

If, in this system, the folders are found to fill to capacity within a short time, some modification is indicated. A classification according to vowels will solve the problem. For one folder per letter, substitute six folders per letter. Again, take B as an example. The six folders would be headed according to the six vowels (Y is considered a vowel for this purpose): viz.,

BA, BE, BI, BO, BU, BY. When deciding the folder for a particular document, select the first *vowel* in the name of the correspondent. For example, Baxter (BA), Beswick (BE), Birtles (BI), Bleasedale (BE), Boardman (BO), Brayshaw (BA), Burgess (BU), Byers (BY). A little practice in this classification will bring proficiency and speed.

Catalogues and Lists. These are indispensable for preparing quotations, checking invoices, etc., and their utility can be enhanced by systematic preservation. Catalogues may be classified into (*a*) pamphlets, (*b*) booklets and (*c*) books. Pamphlets should be kept in folders. Number each pamphlet consecutively, and prefix the numbers with "A." A folder should contain from 30 to 50 pamphlets according to their bulk. Number the tabs of the folders 1–50, 51–80, etc. Booklets are best kept in drawers, and should bear numbers prefixed by "B." Guide cards are inserted at intervals of 20 booklets to facilitate reference. Books should be placed on shelves. Again number, and use prefix "C."

A card index is necessary, though it may be a simple one. The cards will bear the names of merchants and references to catalogues received. In addition to this index, it is well worth while making a second index to subjects (it may be kept in the same case or tray as the other index). For instance, write a card headed "Screwing Machines," and under this heading, as catalogues are received, make a note of suppliers' names. When considering the purchase of such apparatus, turn up the card, which will indicate several sources of supply. This is an example of what is termed "cross-indexing."

Policies and Agreements should be carefully preserved. A good plan is to put each document in a foolscap envelope, number the envelopes consecutively, and keep in a drawer. An index will be necessary if the documents are numerous, and the book type is here suggested in preference to a card index.

Invoices. Before filing away, inward invoices should always be *checked* (quantities, prices, calculations and additions), entered up in the *price list* (it is important to keep this book up to date), and *allocated* to jobs, where the goods are not for stock.

To facilitate the checking of invoices, an *Order Book* (carbon copy, consecutively numbered type) should be used. Its advantages are: Ease of allocation of goods to jobs. A note of the job on the office copy of each order will achieve this end.

Unauthorized purchases are eliminated. Only invoices for goods ordered officially should be passed.

A check upon unexecuted orders is possible by the practice of striking the pen through each copy order as invoices are passed.

Duplicate charges for the same goods are obviated by the check just mentioned.

Outward Invoices may be in respect of (*a*) goods sold, (*b*) work done.

(*a*) *Goods sold.* Use a *Delivery Book* (carbon copy and consecutive numbers). At each month end, the invoices may be prepared direct from the office copies of Delivery Notes. Strike through each copy as invoiced.

(*b*) *Work done.* The source of information is the Cost Sheet for each job (*see under* Costing). Much time is wasted by many businesses in the preparation of invoices. Often a Day Book is used, details of every charge being recorded therein. Subsequently, invoices are rendered by making copies of the Day Book entries. Copying work should be avoided where possible, for not only is it laborious, but mistakes are all too frequent.

Up-to-date Invoice System. Invoice forms are obtainable, numbered consecutively and in duplicate. The duplicate is attached to the original by a perforated stub which is torn off when the invoice has been prepared. The duplicate is obtained by the insertion of carbon paper. The copy invoices are punched to fit special binders. In this way, a "Day Book" or Sales Journal is prepared simultaneously with the invoices. As explained under Book-keeping, the Sales Ledger is entered up (posted) direct from the copy invoices.

Wages Records. The premiums on Employers' Liability and Public Liability policies are based upon wages paid during the previous 12 months, and it is useful to keep a book for recording wages which must be included in the annual declaration. The gross wages (i.e. before deducting National Insurance, Income Tax, etc.) are the figures required.

In the case of the Employers' Liability return, it is clearly necessary to eliminate from the gross total the proprietor's drawings or "salary" (which are sometimes put in the Wages Book); otherwise, a higher premium than is necessary would be charged.

Tax deduction cards under the Pay As You Earn system will also help to provide the above information. The column headed "Total gross pay to date" gives (at week 52) the total of the year. As the income tax year ends on 5th April, however, this may not coincide with the insurance year.

Also, there may be employees whose wages are not taxable, and for whom there are no tax cards. These points should be remembered if tax cards are used to provide figures for insurance purposes.

OFF-SITE ASSEMBLY. *See* Pre-Fabrication.

OHM. Standard unit (international) of electrical resistance. Equals resistance offered by a circuit in which a voltage (E.M.F.) of 1 volt permits a current of 1 ampere to flow. Foundation of whole system of practical electrical units.

Ohmmeter. Instrument for measuring resistance directly in ohms on a scale. The best known form is perhaps the "megger" used for measuring high values of resistance. Insulation resistances and leakages in supply circuits are usually measured in megohms (one million ohms). For illustration of the "megger," with an account of its method of use, *see* Faults.

OIL FUEL: CENTRAL HEATING AND DOMESTIC SERVICES

By G. J. Gollin, M.A., M.I.Mech.E., F.Inst.Pet., M.Inst.Fuel

Chief Engineer, Fuel Oil Technical, Shell Petroleum Co., Ltd.

This contribution deals with liquid fuels and their use in boilers for heating and hot water supply. The characteristics of fuel oils are explained, and the principal methods of firing described. Oil-burning installations are described with details of automatic burners. *See also* Boiler: (5).

It is a popular fallacy that liquid fuels burnt in boilers are "crude oils." Crude oil is a term applied to the crude petroleum as obtained from the well. Apart from rare exceptions such oils are not sold commercially as fuel oils. The majority of fuel oils are essentially "residual" oils—that is, crude oils from which the lighter fractions such as motor spirit, kerosene, and perhaps lubricating oils have been boiled off. These residual oils, having lost their lighter fractions, are safe to handle and when supplied to a good burner form excellent fuels.

The second of the two most common forms of fuel oil is the grade known as distillates and these, like motor spirits and kerosenes, are boiled off crude oils. They are, in a manner of speaking, a heavier and more viscous form of kerosene. Most residual oils are dark in colour and viscous, while the distillates are clear and liquid. In addition to these two types there is a host of intermediate grades of oil which are made by blending distillates and residual oils.

Characteristics of Liquid Fuels. To understand the combustion of fuel oil, one must know something about its properties. These are briefly enumerated.

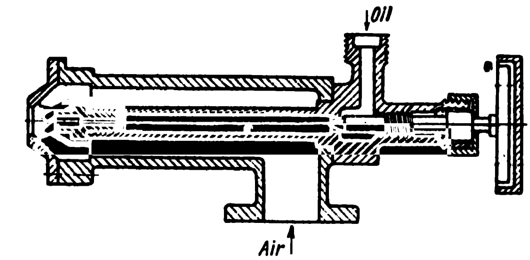
Specific Gravity. This is the ratio of the weight of a given volume of fuel oil to that of the same volume of water. In general the specific gravity of fuel oils lies between 0.85 and 0.99. Thus they are lighter than water.

Viscosity. This, as will be shown later, is a highly important characteristic of fuel oil, being an indication of fluidity. It is measured commonly in a Redwood No. 1 viscometer, which shows the time taken for 50 c.c. of the oil at a given temperature to run out of a fixed orifice. As an illustration, water would take about 27 seconds, a distillate 35 to 40 seconds, and a heavy residual fuel oil perhaps 3,000 to 6,000 seconds. As a preliminary to the combustion of fuel oil it is usually necessary for good atomization to reduce viscosity. This characteristic is so important that it is normal to refer to fuel oils by their viscosity at a standard temperature, usually 100° F. Five typical commercial grades of fuel oil sold in the U.K. have viscosities respectively of 35, 40, 200, 600 and 1,500 seconds Redwood 1 at 100° F.

Flashpoint. The flashpoint of a liquid is that temperature at which it gives off sufficient quantity of vapour capable of

being momentarily ignited. In most fuel oils the flashpoint is somewhere between 180° and 210° F., so that they can be stored and handled with the greatest degree of safety. In dealing with fuel oils, consideration need not be given to the Petroleum Acts, which cover only those petroleum products having a flashpoint below 150° F.

Calorific Value. The most important characteristic of any fuel is its calorific value. By this it can be compared with other fuels, since the calorific value is an indication as to the number of heat units which in a perfect boiler system could be obtained from 1 lb. of the fuel if completely burnt. The unit used is British Thermal Unit (*which see*). Normally the range of fuel oils has calorific values varying from 18,500 to 19,400 B.Th.U. per lb. Thus 1 lb. of fuel oil offers four times the heat units presented by 1 lb. of wood, 60% more than 1 lb. of coke, and at least 30% more than 1 lb. of anthracite.



OIL FUEL. Fig. 1. Injector burner for spraying oil as a fine mist by means of jet of air.
Courtesy of I.a Drew & Co., Ltd.

This high calorific value has played an important part in the adoption of liquid fuel for domestic purposes, since it considerably reduces the weight of fuel to be burnt in the heating season and hence the amount to be kept in storage. Apart from this the space devoted to storage is reduced to a minimum, as liquid fuel is very compact, occupying only 40 cu.ft. per ton.

Burning of Fuel Oil. It is extraordinarily difficult to ignite fuel oil in bulk. In order to get it to burn satisfactorily it is necessary to use an oil burner. Burners can be roughly divided into two classes: (*a*) Vaporizing; (*b*) Atomizing.

Vaporizing Burners. These are burners in which the fuel oil is vaporized by being brought into contact with a surface heated by the flame. Such burners are chiefly fitted in small appliances and burn up to about 1 gallon of oil an hour. They give excellent service for small water heaters and space heaters. They are mostly designed to handle kerosene, and hence are outside the scope of this article.

The fan-assisted vaporizing burner, although confined to handling fuels of the lighter grades, is capable of being manufactured to burn up to about 8 gallons of oil per burner per hour.

Atomizing Burners. This burner, instead of gasifying the oil, sprays it into a fine mist. This can be done in two ways—by the injector system, or the pressure jet.

Injector Burners. In these a jet of steam or air is made to impinge on a column of oil, which is thus mechanically broken up into fine drops. (*See* Fig. 1.)

Rotary Burners. These, too, are of the injector type, where the moving oil is broken up by a blast of low pressure air. Instead of the oil issuing from a single orifice or from several, it is thrown into the air stream from the edge or mouth of a rapidly rotating hollow cone. The oil feed is arranged to drop on to the inside surface of the cone, or "cup," as it is usually termed. One principle of action of these rotary burners is seen in Fig. 2.

Pressure Jet Burners. No atomizing medium is employed. The oil is pumped under high pressure through a specially designed nozzle. The nozzle is so constructed that the oil is given a rotary motion in its interior. This rotation is considerably accelerated as the oil leaves the final orifice, so that the column of oil

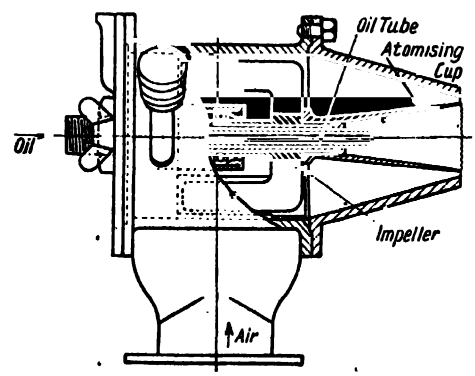
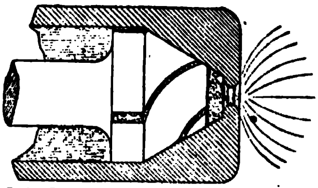


Fig. 2. Rotary burner in which oil sprayed by atomizing cup is broken up by blast of low pressure air.
Combustions Ltd.

should leave the burner nozzle in the form of a rotating hollow cone. This cone widens under the influence of centrifugal force, until the surface tension of the oil is overcome and the conical spray disintegrates into a fine mist. (*See* Fig. 3.)



OIL FUEL. Fig. 3. Pressure jet burner in which rotary motion imparted to oil breaks it up into fine spray.

Effect of Viscosity on Atomization. The performance of all burners depends upon the viscosity at which the oil arrives at the burner. If the oil should be too viscous the atomization will be coarse, the combustion poor, and the flame streaky. It is essential, therefore, that the oil should arrive at the burner at the correct viscosity, and to effect this it may be necessary to pre-heat the oil in order to raise its temperature and reduce its viscosity to the required figure. The correct viscosity will depend upon the type of burner being used. Some burners can atomize an oil at 200 seconds viscosity. With pressure jet burners, however, the nozzle will atomize only if the viscosity of the oil is reduced to about 55 seconds in the case of small burners, or 100 seconds in the case of large burners. A typical "viscosity-temperature" curve is here given. (*See* Fig. 4.)

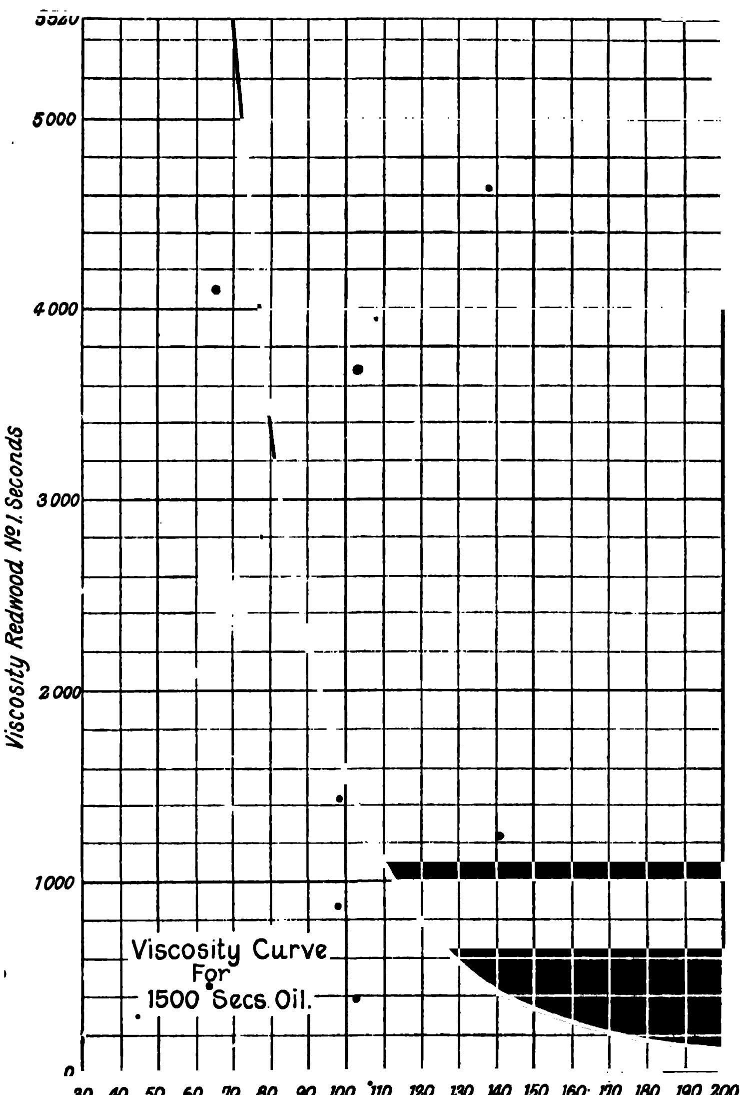


Fig. 4. "Viscosity-temperature" curve for "1,500 secs. Oil"; viscosity measured by Redwood No. 1 Viscometer (see text pp. 715 and 717).
Shell Petroleum Co., Ltd.

Combustion Air. An average fuel oil would need for each pound of oil burnt some 19 lb., or 240 cu. ft. of air. Therefore, in addition to the comparatively small amount of air which may be used for atomizing purposes a considerable further quantity must be supplied to the combustion chamber. It is very important that the air is introduced correctly with respect to the atomized oil, as the good mixing of the 19 lb. of air with each pound of oil is essential if clean and efficient combustion is to be obtained. An insufficiency of air will result in smoke and carbon formation. An undue

excess of air will chill the flame and increase both volume and temperature of the waste gases leaving the chimney.

In modern boiler house practice it is unusual to allow the amount of air put into the combustion chamber to depend upon a somewhat indeterminate suction induced by a chimney. For accuracy of control the air for combustion should be either blown into the combustion chamber by a forced draught fan, or sucked into the combustion chamber by an induced draught fan. In both cases the air passes through carefully designed devices, known as air directors, which ensure the correct mixing of the oil and air so as to give stable flame. (*See* Fig. 5.) The modern semi-automatic control does not merely increase or decrease the size of the flame, but also simultaneously adjusts the amount of combustion air, so that whether the burners are working on a high or a low flame a reasonably high standard of combustion efficiency is maintained.

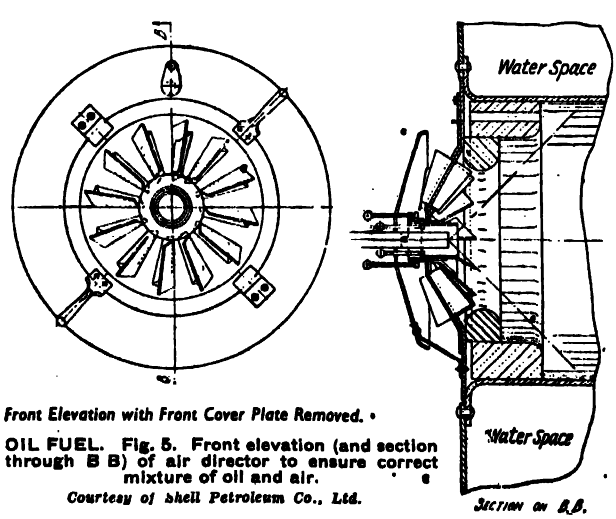
OIL-BURNING INSTALLATIONS

Generally the boilers that are fired by oil burners are the same as those manufactured for use with solid fuels. The larger boiler installations usually have operators permanently in attendance, and so are either hand-controlled or equipped with semi-automatic controls. In this type of installation the heaviest and most viscous grades of oil available can be burnt.

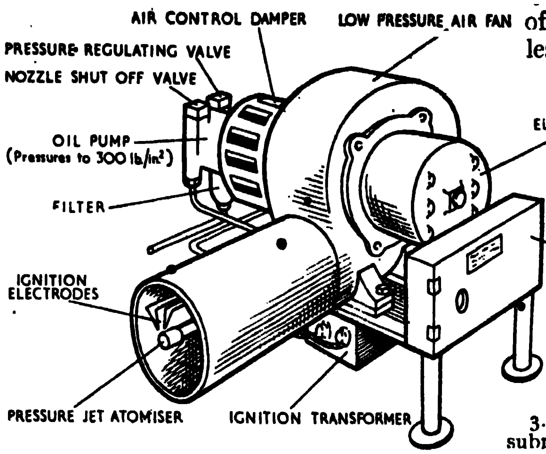
Small installations usually contain one or more cast-iron sectional or welded steel boilers. Generally a fully automatic oil burner is applied to each boiler. These automatic burners light themselves and run intermittently at the dictate of thermostats placed either in the rooms to be heated, in the flow to the radiators, or (in the case of domestic supply) in the secondary water space of the calorifier. Burners are also regulated by controls which are operated by the steam pressure of the boiler.

In the larger commercial and industrial installations the burners and their air directors are mounted on the boiler front while the auxiliary gear, that is, pumps, heaters, fans, and electric motors, are usually mounted on bedplates in a suitable position in the boiler room. The requirements of domestic buildings led to the development of the fully automatic burner in which all the components are mounted in one unit as indicated in Fig. 6. Although there are automatic burners of the rotating cup and medium pressure air types, a census shows that some 80 per cent of all fully automatic burners of the intermittent type use pressure jet atomization. The burner shown in the illustration is of this type.

The nozzle and electrodes are mounted in what is known as the draught tube which leads the air from the fan into the combustion chamber around the oil spray. Various devices (not shown) have been developed by burner manufacturers and installed in the draught tube with a view to obtaining satisfactory mixing of the air with the oil spray and the maintenance of a stable flame near the burner nose. These conditions would not be obtained if the air were blown through a plain tube around the nozzle. A good burner of this type should produce a stable flame with excess air not exceeding 40 per cent. equivalent to a CO_2 content in the dry flue gases of 11 per cent. The chimney losses increase very rapidly if the quantity of air introduced into the boiler is adjusted to be much in excess of that theoretically required for combustion, hence the less air needed to maintain a stable flame, the more efficient is the burner. A CO_2 indicator is of the greatest importance for enabling the installer to tune the burner, or the customer to check the efficiency.



OIL FUEL. Fig. 5. Front elevation (and section through B B) of air director to ensure correct mixture of oil and air.
Courtesy of Shell Petroleum Co., Ltd.



OIL FUEL. Fig. 6. Automatic pressure jet burner of atomizer type.
Shell Petroleum Co., Ltd.

Burners of this type are installed in thousands all over the world with capacities normally for domestic use of the order of 1 to 2 gallons per hour which at 70 per cent efficiency would be equivalent to an output of 120,000 to 240,000 B.Th.U/hr.

The British oil burner industry has developed burners of this type with fuel consumptions up to 50 gallons per hour and have produced ingeniously modified burners equipped with preheaters which enable them to handle more viscous and cheaper grades of oil than that normally supplied for central heating purposes.

The manner of installing an automatic burner is shown in Fig. 7.

The oil is stored in a welded steel cylindrical or rectangular tank made up of plate not less than 3/16 in. thickness fitted with

(*a*) Manhole and cover; (*b*) filling pipe; (*c*) vent pipe; (*d*) feed pipe to the burner; (*e*) drain pipe; (*f*) oil level indicator.

The vent pipe is necessary to enable air to enter the tank to replace the oil which passes to the burner but its other function is to prevent an excessive air pressure from being built up in the tank while it is being filled. For this reason the diameter of the vent pipe should never be less than the diameter of the filling pipe.

Even for the smallest installations the capacity of the storage tank should not be less than 750 to 1,000 gallons so as to keep in hand a supply for a reasonable period. Gauges to show the amount of oil in a tank usually belong to one of the three following types:—

1. A float connected by a chain or wire over a pulley to an indicator which goes up and down against graduations painted on the outside of the tank.

2. A float on a hinged arm connected to a magnet which rotates an indicating needle on a dial on the outside of the tank.

3. A pneumatic gauge consisting of a chamber submerged at the bottom of the tank and connected by means of a small bore tube to a pressure gauge or manometer mounted in a convenient spot in the boiler room. The pressure indicated on the manometer is proportional to the static head of oil in the tank and hence the gauge can be calibrated to read gallons of oil if the specific gravity of the fuel is known.

The pipe leading the oil to the burner is taken off the side not less than 3 in. from the bottom so as to avoid sludge or dirt which may have settled down to the bottom of the tank. All storage tanks should have a drain connexion at the bottom so that sludge can be run off regularly. The tank should be mounted on its piers so that the bottom of the tank slopes ½ in. per foot towards the drain connexion.

The drain valve itself should be of the lockshield type so as to avoid interference by unauthorised persons. The authorities in certain urban districts issue recommendations regarding the layout of the storage arrangements for oil-fired installations and any requirements such as catchpit walls, fire-valves, etc., should be

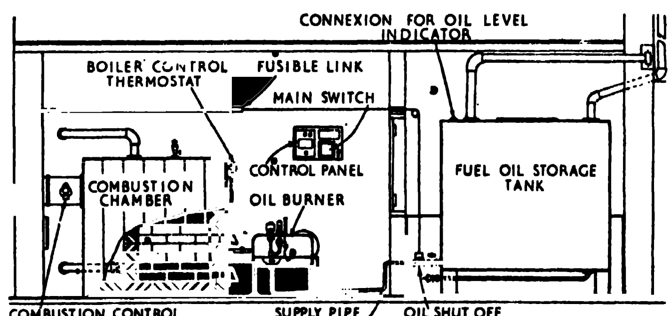
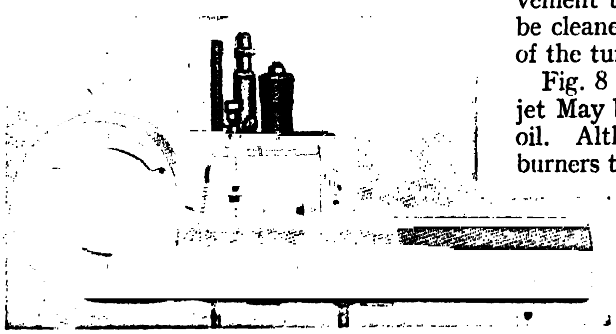


Fig. 7. Fully automatic oil heat installation showing typical arrangement. The combustion control thermostat stops burner and oil supply in case of flame failure, and the boiler control stops combustion at required temperature or steam pressure. Note the fire-prevention fusible link controlling a shut-off valve.
Courtesy May Oil Burner (Eng.) Ltd.

adopted. Fig. 7 shows a fire-valve fitted in the feed line to the burner after the essential shut off valve. This fire-valve, which is either spring or deadweight loaded, is held open by the wire stretched over a pulley across the boiler room. At intervals the wire is joined by fusible links so that if fire broke out in the boiler room, the wire would part and the valve would shut off the oil supply.

Most of the oil pumps fitted on automatic oil burners have a capacity of about 12 to 20 gallons of oil per hour and as the output of the atomizer usually is only 1 or 2 gallons per hour, the pump delivery is considerably in excess of the quantity being burned. By allowing this excess to escape through a spring loaded relief valve, one can maintain the pressure of the oil at the atomizer at a desired figure. The surplus oil leaving the relief valve can either be led back to the suction side of the pump by a pipe connexion within the burner assembly as shown or can be taken through a separate line back to the top of the main storage tank.

The simple layout in Fig. 7 can be used where the storage tank is not far away from the burner and the level of the tank relative to the burner is such as to produce a gravity head at the burner pump whatever the level of oil in the tank. Where, however, the tank is far away or below the level of the burner this single pipe system gives little opportunity of purging from the pump and suction line any air which may have been sucked into the system through the pump gland or elsewhere. In all such cases the separate suction and return lines give more reliable operation, but in order to avoid excessive friction the size of these lines must be considerably larger than that for the single-pipe system because in the single-pipe system the line only passes the oil being delivered by the burner nozzle, while in the two-pipe system the suction line carries the full pump capacity and the return line the pump capacity minus the atomizer capacity.



OIL FUEL. Fig. 8. Fully automatic pressure jet burner for light oil. *Courtesy May Oil Burner (Eng.) Ltd.*

As the pressure jet nozzle of normal domestic capacity contains very small passages it must be protected from choking by a suitable filter. When dealing with light oils the filter should be not coarser than 100 mesh. It is very convenient to use filters of the type that can be cleaned without dismantling by means of the turn of a handle.

Fig. 8 shows a fully automatic pressure jet May burner designed for use with light oil. Although the majority of automatic burners throughout the world handle light distillate oils, the British burner industry has developed fully automatic burners for heavier grades. Several are now available designed to handle an oil with a viscosity of 200 seconds Redwood 1 at 100° F. Electrical preheating arrangements thermostactically controlled deliver oil at a suitable pressure and at 180° F. to the atomizer. Ingenious arrangements ensure the arrival of hot oil at the nozzle when the burner starts so as to obtain prompt and safe ignition.

The electric controls supplied with automatic burners are designed so that when the thermostat calls for heat the burner goes through all the normal stages of lighting up in correct sequence. In conjunction with the safety flue thermostat, or a radiation-sensitive device such as a photo-electric cell, the control box will shut down the burner should flame ignition not be safely achieved during a starting cycle or the flame be accidentally extinguished while the burner is running.

Seeing that an automatic oil burner is called upon to carry out the functions both of an oil-burning device and of a furnace operator it is not fair to expect it to function indefinitely without reasonable attention. It is advisable to ask the maker to carry out a routine inspection and service call, say, three times per year.

Combustion Chambers. Uusually the combustion chamber provided for solid fuel is adequate for burning a liquid fuel. The fire bars are, of course, unnecessary and should be removed; or if fixed they

can be covered with a layer of refractory brickwork (*see* Fig. 9). The principle in designing a brick lining for a combustion chamber in which to consume oil fuel is that there should be as little brick as possible consistent with the following two requirements:

(1) To protect the mud space and other vulnerable points in the boiler.

(2) To shield the flame in its initial stage from the violent cooling effect of relatively cold surfaces.

Provision should be made of a refractory quarl through which the burner fires, and a certain amount of brickwork round the root of the flame so as to improve the quality of combustion; but it is essential that the flame shall burn in free suspension and not impinge on this or any brickwork. Although the brickwork may appear to be red or even white hot, it is considerably cooler than the flame. The flame, if brought into contact with the brickwork, will be unduly chilled—with the result that combustion will not be completed and there will be carbon formation on the brickwork.

ONCOST. This article explains the calculation of the percentage which must be added to Prime Cost in order to cover Oncost. For the principles of costing the reader should refer to the article on Costing, where the general subject is treated.

As explained under the heading Costing, Oncost means those indirect expenses such as rent, rates, office salaries, and expenses which cannot be charged direct to jobs. (*See also* Prime Cost.)

Under the heading Balance Sheet, a set of annual accounts is given, and the calculations in the present article are based upon those figures, to which the reader should refer.

Turning first to the Trading Account (page 82), it will be seen that the Prime Cost of Work Done (£7,825), is £6,900:

Stock, Jan 1st	£1,000
Purchases	4,000
Wages	3,000
Travelling expenses	100
	£8,100
Less Stock, Dec. 31st	1,200
Prime Cost	£6,900

Next refer (p. 82) to the Profit and Loss Account, where the expenses (*i.e.* Oncost) are found to total £725; in other words, the invoicing during the year must have been at least £6,900 plus £725 (£7,625) to clear Gross Cost. Actually it amounts to £7,825, leaving a net profit of £200.

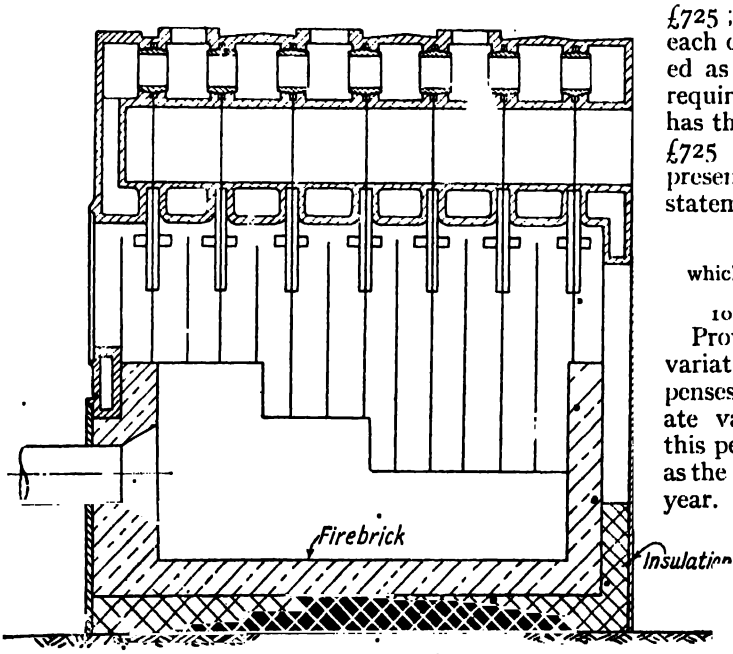
The two figures to keep in mind are Prime Cost of work £6,900, and Oncost £725; their relationship to each other must be expressed as a percentage, *i.e.* we require to know what figure has the same ratio to 100 as £725 has to £6,900? Or, presented as a proportion statement,

$$X : 100 :: 725 : 6900$$

which gives $\frac{100 \times 725}{6900} =$

$10\frac{1}{2}$ per cent. (approx.)

Provided there are no variations of overhead expenses without a proportionate variation in turnover, this percentage can be used as the Oncost for the current year. This calculation should be made annually, because business conditions vary. When figures are available for several years an



OIL FUEL. Fig. 9. Combustion chamber for oil-fired sectional boiler.
Shell Petroleum Co., Ltd.

Oncost: Itemized Percentage to Prime Cost

	£	Percentage to £6,900
Rent and rates	100	1·45
Printing, etc.	50	0·73
Repairs to plant	10	0·14
Repairs to motor	15	0·22
Proprietor's salary ..	300	4·35
Office expenses	200	2·90
Insurances	50	0·72
		10·51

average should be computed, as the longer the period upon which the percentage is calculated, the more reliable will it be.

Not only is the calculation valuable as data for charging and estimating current work; it provides, year by year, a check on overhead expenses. If there is a large increase in any one year, inquiry should be made as to the cause. The search will be narrowed down if *each* item of expense is related to Prime Cost, as here shown.—*R. A. Price, A.C.I.S.*

ONE-PIPE SYSTEM OF DRAINAGE

By F. C. Cook, M.R.San.I., R.P.

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After a short review of the history of this system, the general principles are set out and it is compared with the Dual system. The testing of the system is described. A final section deals with the planning of installations. Extracts are given, with comments, from the Minimum Specification of the Institute of Plumbers. A notable feature of this contribution is the presentation in the Frontispiece to this volume of a series of photographic illustrations of one-pipe units. See Flat; Hospital: (I), etc.; *also* various legal articles referred to below.

Before explaining the principle of the system of drainage known commonly as the "one-pipe" system it will be as well to review briefly the history of its introduction and regulation by by-laws. The various Acts and By-laws affecting sanitation are discussed by the Legal Editor elsewhere in this work under the headings Acts and By-laws; London County Council By-laws; Metropolitan Water Board; and Public Health Acts.

The London County Council formulated By-laws in 1893, and they remained in operation with a few alterations until 1930, when a general revision took place. Prior to 1893, the local authorities did very much as they chose, and there was no uniformity of sanitary law in the London area. It was about 1930, when the new By-laws came into operation, that the "one-pipe" system was talked about, and one Borough Council sanctioned its installation in several large buildings; it proved a success, and subsequently became general practice in that borough. The London County Council again revised their "drainage" by-laws to embody the principles of the one-pipe system, which came into operation in 1934.

It is now possible to instal either the one-pipe system, or the separate system (*i.e.* soil pipe and the waste pipe—which will be referred to in this section as the dual system); or, if the conditions warrant it, both systems can be used on the same building. Instances of old work carried out on the one-pipe system can be found in various parts of the country, but not installed under by-law requirements; possibly they were fixed without notifying the local authority, or else a concession was obtained from that authority.

The system has been in vogue in America and a few continental countries for some years, and has proved a marked success. The Ministry of Health's Model By-Laws of 1930 provided for its installation, as also did their revised By-Laws of 1937, although the details are somewhat meagre. The Model By-Laws are adoptable by local authorities outside the London area, and carry statutory value.

Principle. The general principle of the one-pipe system of drainage is for the discharges from washing fitments (*i.e.* baths, lavatory basins, sinks and bidets) to go into one main pipe which may or may not receive the discharge from soil fitments (*i.e.* closets, urinals or slop closets) and that such pipe be connected to the drain direct. In addition, any of the stated washing fitments may be connected direct to the drain without the

interposition of a gully trap, in a similar manner to that for soil fitments. Further, provision of a system of ventilation is necessary whereby the traps of all the fitments will maintain a specified water seal. The term "one-pipe" implies that one pipe shall act as a general waste, whereas previously two pipes were installed to do the same amount of work.

Comparison with Dual System. Under the dual system, excremental filth is discharged into a soil pipe and connected direct to the drain, while discharges from washing fitments are connected to a waste pipe which, before entering the drain, must pass into or over a gully trap, thus providing complete disconnexion from the drain and allowing a current of air to pass up or down the waste pipe, according to varying circumstances. When the main waste pipe is not in use, upward currents are induced within the pipe, due to convection caused by the temperature difference between the air inside and that outside the pipe, brought about by the waste pipe absorbing heat from warm discharges from the fitments, and possibly radiation from the sun. When a washing fitment is discharged, the air within the pipe which is in contact with the fouled surface is forced out at the gully level, and may be situated within a well-hole of a block of flats; in addition, cabbage water (which is always objectionable) finds its way into the same gully, causing annoyance to the occupants whose windows happen to be open.

A gully trap receiving the waste pipe discharges is usually found to be in a very foul condition, particularly below the grating; this causes emanations of foul air to pervade the atmosphere in the vicinity, diffusion being relied upon to mitigate the nuisance. It is therefore necessary that gully traps be periodically cleansed by hand.

Of recent years soap has been placed on the market in flake form and sold in cartons; this, when used in excess, as in washing silken articles, fills the waste pipe with soap bubbles on discharge, and the bubbles are forced through the grating of the gully on to the adjacent paving, leaving a deposit of soap fat together with some filth. Much time and expense have been devoted in attempts to obviate this nuisance, particularly when the gully has a sealed cover (which is required if situated within the premises). The writer's experience on this point is that the soap bubbles which fill the pipe are forced through the branch waste pipes and traps into the lavatory basins of the lower floors, when a second discharge from an upper fitment is made. When similar fitments are installed on the one-pipe system no such complaint can arise, as the resistance of a trapped gully does not exist.

When a number of washing fitments are connected to the main waste pipe, a main ventilation pipe is installed to receive the branch vent pipes from the traps of each fitment, so that the water seal of the traps shall be maintained (*see* Anti-siphon Pipe). It is necessary, therefore, to install two vertical stacks in connexion with the washing fitments.

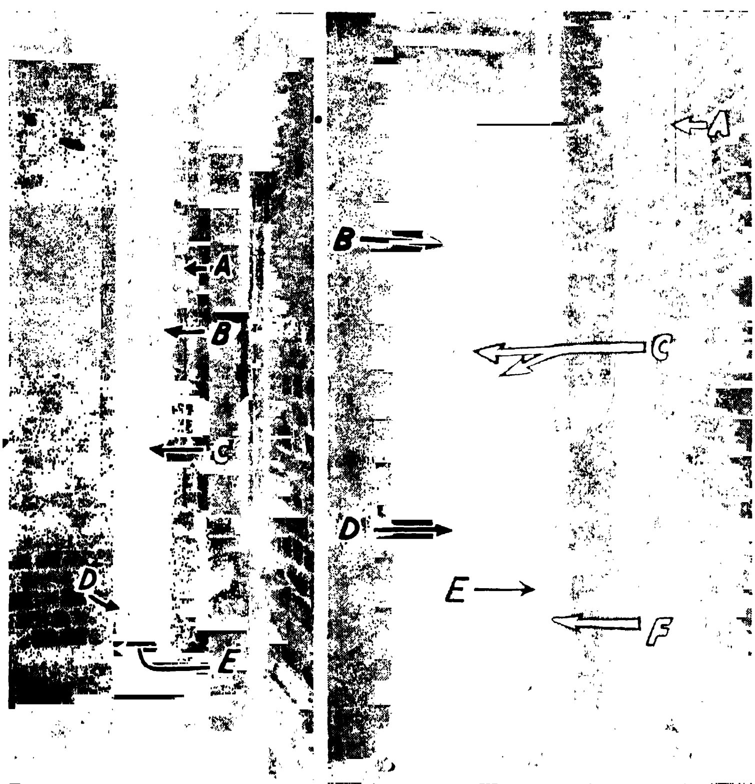
With regard to the soil fitments, where more than one is connected to the soil pipe a main ventilation pipe is installed which receives the branch ventilation pipe from the trap of each fitment. It will be noted that four main vertical pipes are necessary for the dual system to function properly (Fig. 1, on Frontispiece to this volume).

In the one-pipe system, on the other hand, the combined soil and waste pipe, the waste pipe discharging direct to the drain (or the connexion of the lowest fitments to the drain direct), together with adequate provision for ventilation of the traps of all fitments involved, constitute collectively or separately the principle.

A. REVIEW OF ONE-PIPE SYSTEM

The one-pipe system is particularly adaptable where sanitary fitments are grouped and are repeated on succeeding floors, such as one finds in residential flats and hotels. It is more economical to arrange the fitments so that the branch waste and ventilation pipes will be as near the main stacks as possible, forming a circuit from the waste to the ventilation stack, using the lower part of the circuit as a waste pipe and the upper part as a vent pipe; vertical branch pipes can be inserted to take the discharges from the washing fitments, with the traps connected at their required height (Fig. 1a, on Frontispiece).

It will be readily seen that to carry out the work by this system only two main pipes are installed (*i.e.* main waste



ONE-PIPE SYSTEM. Figs 2 and 3. Vertical ducts inside building to conceal piping : (left) A, expanded metal covering ; B, 1½-in. lead pipe rising main; C, 2-in. copper c.w.s. pipe to domestic h.w.s.; D, ¾-in. copper supply pipe ; E, 9-in. by 4½-in. chase in brickwork. (Right) A, electric conduit ; B, 1-in. copper supply pipe ; C, 2-in. copper flow and return pipes before insulation ; D, 18-in. by 4½-in. chase in brickwork, finally brick faced; E, 1½-in. lead rising main in back angle of chase ; F, electric cable conduit.

Courtesy of Messrs. Elsworthy, Ltd.

Note.—Figs. 4 & 5 are on Frontispiece to this volume

and main ventilation pipes) and that the branch waste and ventilation pipes will be practically similar in both systems.

It may be expedient to have a larger main ventilation pipe, when used in a high building of some eight to ten floors, if the one-pipe system is installed. In such case the pipe is usually 3 in. in diameter, while the size used in the dual system for ventilating similar fitments would be 2 in. in diameter for the closets, and 2 in. for the washing fitments. The cost of the two main pipes for the one-pipe system must necessarily be less than that of the four used in the dual system.

The Pipes. It is usual in residential flats to install the vertical waste and ventilation pipes inside the building, as the modern architect objects to having the front external wall defaced with a conglomeration of pipes. The vertical pipes are fixed in chases or ducts; the former are purposely made in the brickwork (Figs. 2 and 3) while the latter are constructed of breeze slabs. (*See under* Flats *and* Building Construction for other illustrations). The use of inside pipes is an advantage from a constructional point of view, as it shortens the branch pipes, facilitates the general construction and obviates cutting away and making-good brickwork.

Provision for Pipe Chases and Ducts. When long lengths of branch ventilation pipes are necessary and required to be chased into the wall, it is good practice for the bricklayer to insert in the course of brickwork a length of 3 in. × 2 in. timber, which can be subsequently removed for the reception of the ventilation pipe and will allow for a rise in its length ; the chase can be covered with expanded metal and faced with

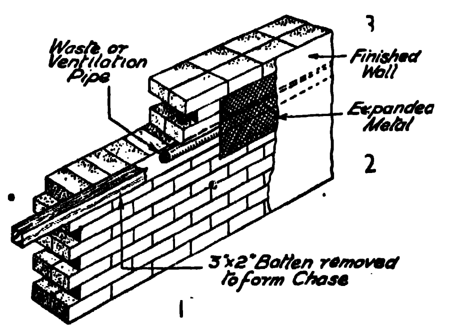
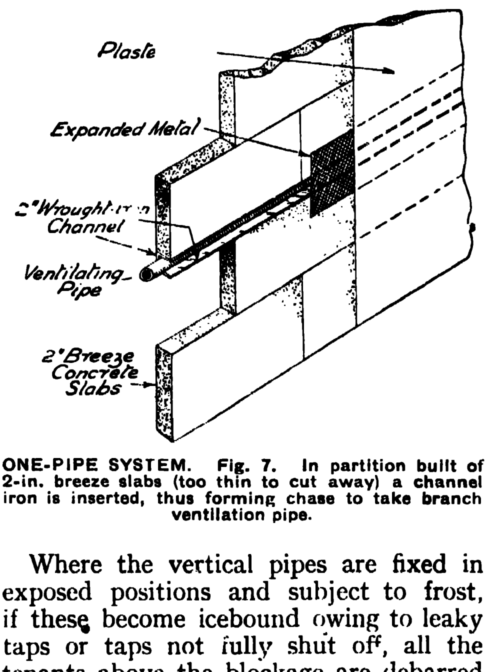


Fig. 6. Chase in brickwork for ventilation pipe, showing three stages : (1) batten inserted during building (removed later to leave chase) ; (2) expanded metal facing to chase ; (3) finished wall face.

plaster work (Fig. 6). This obviates the cutting away of brickwork. With 2-in. breeze slab partitions, the depth of the slab does not permit the cutting away for a branch ventilation pipe, and a good method is to insert at the appropriate position a 2-in. channel iron, which can be faced with plaster work (Fig. 7).

Another advantage of fixing the vertical pipes inside the building is that there is no possibility of their becoming frost-bound during a spell of cold weather, seeing that the general heat of the building and possibly hot water service pipes installed in the duct are sufficient to keep the temperature above freezing point.



ONE-PIPE SYSTEM. Fig. 7. In partition built of 2-in. breeze slabs (too thin to cut away) a channel iron is inserted, thus forming chase to take branch ventilation pipe.

Where the vertical pipes are fixed in exposed positions and subject to frost, if these become icebound owing to leaky taps or taps not fully shut off, all the tenants above the blockage are debarred the use of any fitment on that stack until the blockage is freed. In the meantime the first flat above the blockage may become flooded, via the closet, by users not aware of existing conditions. This consideration alone warrants at least the waste pipe being fixed inside the premises, or being placed where it is not exposed to frost. Some architects still prefer the vertical pipes fixed in the well-holes or inner courtyards, with the branch wastes connected externally. (*See* Figs. 8 and 9 in Frontispiece).

Ventilation Pipes. The termination of the main ventilation pipe can be carried up independently, and to the same height as the top of the soil or waste pipe, or can return to such pipe at a convenient point above the highest fitment. The advantage of the latter provision is that it gives economy without lack of efficiency, and is applicable to a position where the soil or waste pipe receives its highest discharge two or more storeys from the top of the building and has possibly a mansard roof to negotiate. This point is illustrated by Fig. 1 of the article on Flats, page 421.

The lower end of the main ventilation pipe is connected to the main soil or waste pipe at a position not nearer than 9 in. or more than 2 ft. from the invert of the last connexion to the soil or waste pipe, or may be connected direct with the drain or manhole. *See also* Flats, Fig. 1 referred to above.

This provision is enforced when the invert of the last connexion to the soil or waste pipe is less than 10 ft. from the invert of the drain. Its purpose is to avoid air compression (*see* Back Pressure) at the foot of the soil pipe, set up by the fall of discharge from fitments situated on upper floors. This would otherwise disturb the water seal of the traps of the lowest fitments by back pressure in the branch waste pipe, irrespective of the branch ventilation pipe. It is good practice for the branch wastes of the lowest fitments (situated in the basement) to be connected together and to discharge direct into the manhole, thus obviating any possibility of back pressure. The branch ventilation pipes are also connected together and join the main ventilation pipe on the floor above, rendering it unnecessary for the main ventilation pipe to join the main soil or waste pipe, as previously described, seeing that the prescribed 10 ft. will be exceeded.

The one-pipe system is also suitable for houses, providing the sanitary fitments are conveniently grouped; for instance, a lavatory basin situated in a bedroom on each of the two sides of the bathroom could be connected to the waste and ventilating circuits taking the bathroom fitments; and possibly the hall floor cloak closet and lavatory basin, together with the kitchen or pantry sinks, could be connected to the same stack. The soil and ventilation pipe would thus take the discharges from all these fitments direct to the drain, obviating the installing of a separate waste and ventilating pipe for

the washing fitments, together with a gully trap and its attendant branch drain.

In the older town houses, closet accommodation is usually provided adjacent to the hall, without a lavatory basin in the apartment. This washing fitment is now considered fully necessary, and providing the soil pipe is of standard requirements, it is a very simple job to connect the lavatory basin waste and ventilation pipe to the existing soil pipe, by inserting a junction to receive the waste pipe and an inverted junction for the ventilation pipe.

The system is very adaptable for offices, factories, and hospitals, where a sanitary wing to each floor is constructed and the fitments arranged above each other on succeeding floors, as shown in Fig. 8, Frontispiece.

Traps. The question of traps is one which calls for due consideration, seeing that drain air is immediately behind the water seal of the trap, and the latter may be one fixed to a lavatory basin situated in a bedroom or to a kitchen or pantry sink. The depth of the water seal to traps used for all washing fitments (*i.e.* baths, lavatory basins, bidets and sinks) is not less than 3 in. (under the dual system it is only 1½ in.), which provides greater resistance to siphonage, back pressure and evaporation. All traps must be ventilated by means of a pipe not less than 1¼ in. diameter.

The type of trap must be considered, and the legal requirement on this point is that it should be a "suitable and efficient tubular trap." The tubular form of trap, whether of the P or S type (commonly known as a siphon trap), has long proved a simple and self-cleansing device, and contains the least amount of water compatible with its use; such traps are obtainable of lead or hard metal (*see* text and illustration *under* heading Deep Seal Trap). With an adequate ventilation pipe fixed in its proper position in relation to such trap (*i.e.* not nearer than 3 in. or more than 12 in. from the crown of the trap), and with the flow of the waste water, which prevents fouling the pipe, an ideal arrangement is installed. The trap is proof against siphonage, aspiration and back pressure; in addition, it is quiet in action.

It has been argued that drain air may be absorbed by the trap water and given off into the apartment. Against this it must be remembered that the air within the system is in constant movement, owing to the flushing of the various fitments; air currents passing over the top of the ventilating pipes induce aspiration of pipe air, and convection currents are set up within the pipe by temperature difference between the air within and that outside. With an adequate ventilating system, absorption of drain air is improbable; the only danger of fouled air finding its way into the apartment by reason of the trap is due to decomposing soap fat above the seal. The distance between the water seal of the trap and the fitment should be as short as possible, so as to minimize the area fouled. In addition, the secret overflow from the lavatory basin allows foul odours to arise.

There are a number of patent traps on the market which rely on a small chamber of water for resealing the trap after siphonage has taken place. The purpose of their use is to avoid fixing a ventilating pipe for maintaining the seal. The by-law requirement stipulates that every trap shall be ventilated when fixed on the One-pipe system; therefore resealing traps must be ventilated.

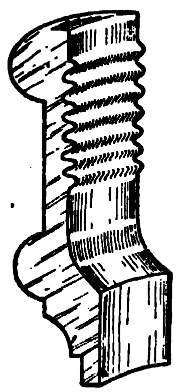
B. PIPES FOR THE ONE-PIPE SYSTEM (LONDON AREA): MATERIALS AND JOINTING

In the London area the following materials are permissible for soil and waste pipes: lead, cast-iron, galvanized wrought iron, and copper.

Lead Pipes. On account of its physical properties, lead is not the best metal to use for main vertical waste pipes, but may be employed to advantage for short branch wastes and ventilating pipes, provided ample provision is made for expansion and contraction (Fig. 10. *See* Frontispiece to this volume). It offers little resistance to the discharge passing through, owing to its smooth bore.

Cast-Iron. This metal has proved quite suitable for vertical waste pipes when protected with a non-corrosive agent such as Dr. Angus Smith's solution. The expansion and contraction of each pipe can be provided for by allowing a slight clearance between the end of the spigot and the base of the socket when fixing the pipe; one-eighth of an inch is sufficient. There are improved sockets for cast-iron pipes which provide recesses

for the molten lead to be caulked into, so as to retain the lead of which the joint is made. (*See* Fig. 11.)



ONE-PIPE SYSTEM. Fig. 11. Section of socket for c.-i. pipe, providing recesses for molten lead in caulking. (*Burn Bros., Ltd.*)

Fittings, such as junctions and bends, are obtainable for practically any position required; they should be carefully examined before use, as small defects, due to faulty casting or roughened interior, may cause trouble when put into use.

Galvanized Wrought Iron. This metal has not found favour for main waste pipes in the London area, probably due to cost, weight, manipulation, and the necessity of re-galvanizing after bending. It is often used for branch waste pipes, and is quite suitable if allowance for expansion is provided. It is not advised for ventilating purposes: condensation within the pipe, absorbing gases arising from decomposing soap fat in the waste pipe, may set up a corrosive action. The corrosion is progressive, with the possible consequence of the pipe being blocked with rust, probably at a bend.

Copper. This metal has been used for vertical waste pipes with marked success. It is comparatively light, tenacious, smooth in bore, adaptable to all positions, and requires little fixing; while its strength and elasticity are other points in its favour. For branch waste and ventilation pipes it can be easily manipulated; allowance should be made for expansion and contraction when fixed in brick chases.

Joints. The legal requirements for joints used in connexion with "One-pipe" work in the London area are set out fully in the London County Council Drainage By-Laws, and provide for any new method or material which may subsequently be placed on the market and meet with the approval of the local authority.

Every joint in such pipe shall be made in the manner and with the jointing materials hereinafter prescribed or otherwise in an equally suitable and efficient manner and with equally suitable material, and so as to preserve the continuity of the pipe without obstruction . . . .

The following are the prescribed methods.

Lead.

(*a*) Of lead, the joints shall be of the kind known as burned, or plumbers' wiped soldered joints.

Lead-burning for pipe joints is finding favour in making up loop systems for bathroom fitments, seeing that most of the work can be carried out on the bench, and there is a distinct saving in plumbers' solder. The art of lead-burning (*which see*) is included in the syllabus of the City and Guilds of London Institute (*which see*) and is taught at most technical institutes. If the plumber can meet the initial cost of acquiring the plant, which is approximately £9, it will soon recompense him, providing he has sufficient work for it. The solder used for the plumbers' wiped joint is composed of lead 2 parts, tin 1 part. For full description of methods *see* Joints (1).

Copper.

(*b*) Of copper, the joints shall be of the kind known as compressed joints made with union nut or flanged couplings, or other suitable joints.

Copper is now largely used for waste and anti-siphonage pipes, and there are a number of different types of compression joints (*which see*) that are adaptable. Under the heading "Or other suitable joints," bronze welding (*see* Welding) is generally accepted by the local authorities, and has proved very satisfactory. The observations made above in respect of lead-burning are applicable to bronze welding.

Cast-iron.

(*c*) Of cast-iron with sockets, the joints shall be (i) made with a gasket of hemp or yarn and metallic lead properly caulked, or (ii) screwed joints with galvanized shouldered cast-iron, wrought iron or metallic iron sockets.

The jointing of cast-iron pipes is fully described under the heading Joints (2).

Wrought Iron with Sockets.

(*d*) Of wrought iron with sockets, the joints shall be screwed joints with galvanized shouldered cast-iron, wrought iron, or malleable iron sockets.

Wrought iron and malleable iron socket joints are extensively used for the smaller diameter waste pipe, and should be constructed on the recess principle so as to preserve the continuity of the pipe (Fig. 12. *See* p. 726).

Cast-iron with Flanges.

(*e*) Of cast-iron with flanges, the joints shall be securely bolted together with some suitable insertion.

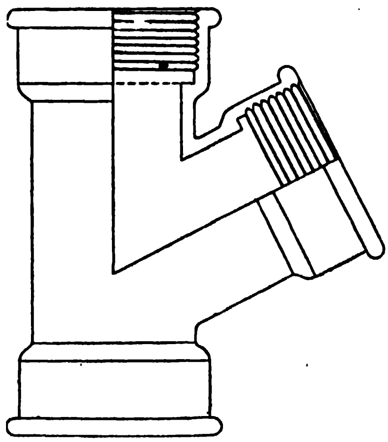
Wrought Iron with Flanges.

(*f*) Of wrought iron with flanges, the joints shall be made with galvanized cast-iron, wrought iron or malleable iron flange unions or flanges

securely bolted together with some suitable insertion.

Both (*e*) and (*f*) are seldom met with for waste pipe work, as cast-iron socketed pipe is available with an extensive range of fittings.

Joint to Closet Outgo. When a P-trap pedestal closet is fixed to an iron junction and the floor is constructed of concrete, the joint should be made of Portland cement; but, if the floor is constructed of wood joists and floor boards, which are subject to shrinkage, then the joint should be made of red and white lead cement and hemp, which will allow shrinkage of the woodwork before the joint becomes hard, thus preventing the weight of the user from fracturing the outlet of the closet, which very frequently occurs when the joint is made of Portland cement.



ONE-PIPE SYSTEM. Fig. 12. Galvanized wrought iron socket joint recessed so as to preserve the continuity of the pipe and eliminate resistance to flow.

Joints from Soil and Waste Pipe to Drain. The following are the usual methods of connecting the main vertical pipes to the drain, and are in accordance with the London County Council drainage requirements.

Lead to Iron. Lead soil and waste pipe to an iron drain: A brass ferrule (sometimes called a sleeve) is connected to the lead pipe by means of a plumbers' wiped joint or by a lead-burned joint, and the joint between the ferrule and iron drain socket is made with a gasket of hemp or yarn and molten lead, which is afterwards caulked flush with the top of the socket.

Lead to Stoneware. Lead soil and waste pipe to a stoneware drain: The brass ferrule is connected to the lead pipe, as previously described, and the joint to the stoneware drain socket is made with one ring of yarn at the base of the socket to prevent the cement from protruding inside the pipe, and Portland cement trowelled off to a triangular fillet.

Copper to Iron. Copper soil and waste pipe to iron drain: The brass ferrule used to make this connexion can be jointed to the copper by compression or capillary joints, bronze welding, brazing or silver soldering, and caulked into the iron pipe with lead as previously described.

Copper to Stoneware. Copper soil and waste pipe to stoneware drain: The brass ferrule is connected to the copper pipe as previously described, and connected to the stoneware drain with a ring of yarn and Portland cement.

Iron to Iron. Cast-iron or wrought iron soil and waste pipe to iron drain: The annular space between the pipe and socket which forms the joint is filled with caulked yarn up to one-third its depth, and molten lead afterwards caulked fills the remaining two-thirds.

Iron to Stoneware. Cast-iron or wrought iron soil pipe to stoneware drain: The annular space is filled with Portland cement, a ring of yarn having first been inserted for its retention; the cement is trowelled off to form a triangular fillet at the top of the socket.

Branch Vent Joint. When the main ventilating pipe is constructed of cast-iron and the branch vents of lead pipe, it is common practice to use a brass thimble connected to the lead with a plumbers' wiped joint, the connexion to the main vent being made with a caulked lead joint. This is the weakest joint in the system seeing that the depth of the thimble, which receives the spigot end of the inverted junction, rarely exceeds 1½ in. while the minimum depth of socket on a 2 in. cast-iron pipe is 2¼ in; for a 3 in., 2¾ in.; and for a 4 in., 3 in.

C. TESTING THE ONE-PIPE SYSTEM

It is essential that the whole of the system should be airtight on test, seeing that drain air is now in direct contact with the traps of all sanitary fitments, some of which are situated in bedrooms and kitchens. The By-Law requirement on this point states:

> Such pipes shall be constructed so as to be watertight and to be capable of resisting a pressure of five feet head of water.

The pressure on the sq. in. of 1 ft. head is 0·433 lb., so that the pressure required for 5 ft. head=2·165 lb. on the sq. in.

The usual method of testing new work on high buildings is to insert an access cap in vertical pipe at each floor level, seal ends of all branch pipes, and submit the piping to a water test from the access cap at floor level up to the one on the next floor, which is equivalent to 4·33 lb. on the sq. in. at the plug, for a height of 10 ft.

This is fully necessary, seeing that the vertical pipes are invariably fixed in built-up chases or ducts, with no prospect of rectifying defects when the work is completed. Unfortunately, the most important joint (*i.e.* the joint which connects the fitting to the main waste) cannot be submitted to this test, as it is not expedient to fix the fittings until the partitions and plasterwork are finished. The only test that can be applied to this joint is an air test, giving a pressure of approximately twice the depth of the trap water seal; this, if there should be a closet fixed to the waste pipe, will be about a 3 in. water seal test, equivalent to 0·108 lb. on the sq. in. If only washing fitments are connected to the waste pipe, then with the 3 in. water seal trap approximately 6 in. hydraulic head of pressure can be obtained, which is equivalent to 0·2165 lb. on the sq. in. (*See also* Drains: (3) Examination and Testing.)

As to the efficiency of the system from a siphonic aspect, in installations properly planned regarding ventilation, the writer has taken a number of "cc." (cubic centimetre) tests of water content of traps fixed to bathroom circuits, which have proved highly satisfactory.

Example. A cc. test was carried out on a $1\frac{1}{2}$ in. sink trap fixed to the end of a loop circuit on the first floor. The test consisted of the simultaneous discharge from bath, lavatory basin, closet and sink, on the fifth, sixth and seventh floors, connected to a 4 in. main waste pipe and 3 in. main ventilation pipe.

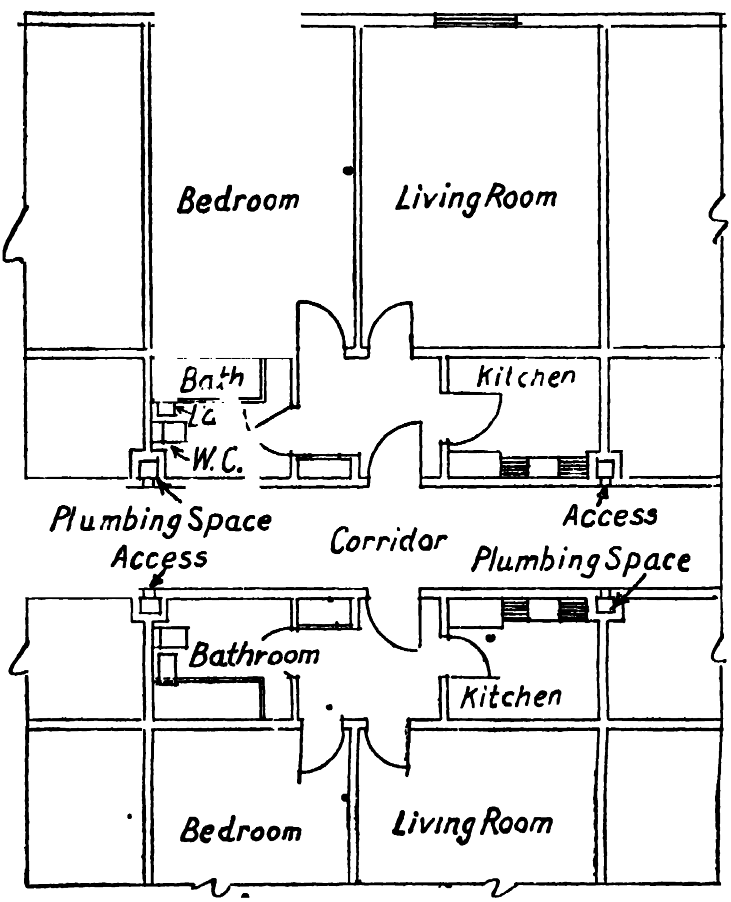
The content of $1\frac{1}{2}$ in. sink trap before test was	240 cc.
The content of $1\frac{1}{2}$ in. sink trap after test was	226 cc.
Loss	14 cc.

The loss of water seal to the closet was $\frac{1}{4}$ inch.

Repeated similar tests, using the same water after first test (*i.e.* 226 cc.), showed no further loss; therefore the resistance of the trap water was sufficient to withstand this abnormal test. A further test was carried out successfully by three persons discharging any of the fitments at will.

D. PLANNING ONE-PIPE INSTALLATIONS

There is a distinct tendency in modern planning to devise high-class residential flats with a central corridor and flats on either side of the corridor (Fig. 13). The



ONE-PIPE SYSTEM. Fig. 13. Plans of two-room flats having internal bathrooms and kitchens. Waste, ventilating, and soil pipes from one bath and pipes from kitchen in adjoining flat are carried in duct between, with corridor access, permitting the use of the one-pipe system.

sanitary fitments are so arranged that a bathroom of one flat and a kitchen from the next flat are connected to the same duct, which has an access door opening on to the corridor. Both these apartments are situated internally and are ventilated mechanically (*see* Flat).

The advantages claimed by adopting the one-pipe system are: two main pipes instead of four; simple design; less maintenance; economy of space when main pipes are fixed inside; absence of foul gullies—therefore, more hygienic system; no risk of frost when pipes are fixed internally; architectural advantage: fewer pipes to disfigure elevation.

Figs. 14–16 on the Frontispiece show one-pipe units for two ground floor flats. Figs. 15 and 16 being the start of the units. The plumbing work shown is carried out in a similar manner on each of the three floors above. The tinned ends of the waste and vent pipe on the right of Fig. 15 and the left of Fig. 16 are to be continued to form a loop for the reception of the several traps (*see* plan).

Several photographic illustrations are given (in the Frontispiece to this Volume), showing copper models of one-pipe units with sif-bronze welded joints. These are typical of actual installations, whether constructed of copper or cast-iron vertical main pipes, and copper or lead branch waste and vent pipes. In all cases the vertical waste pipes can be installed in a chase or a duct, while the branch pipes can be chased into the brickwork or covered with a dwarf slab partition forming a plumbing space behind.

Figs. 17 to 21 are described in detail on the Plate. Note in Fig. 17 that the main ventilation pipe is returned to the main waste pipe for the purpose of taking up the compression of air set up by the change of direction of flow of waste water, as previously explained. This feature occurs in each of the models shown, and is in consequence the first unit connected to the drain.

In Fig. 19 it should be noted that the branch wastes do not connect to the main waste pipe direct. If the installation is entirely of copper, then direct connexion to stack could be made; but with a cast-iron main waste, a 180 deg. cast-iron junction and a short length of 2-in. lead pipe, it can receive a number of lead branch wastes within a restricted depth of floor.

E. INSTITUTE OF PLUMBERS MINIMUM SPECIFICATION

As a general guidance in the installation of the "One-Pipe" system, the Institute of Plumbers have included in their Minimum Specification No. I (1938 edition, 2s. 2d. from the Secretary, Institute of Plumbers, 81, Gower Street, W.C.1) a section covering this system.

The name selected to define what is commonly known as the "One-Pipe" system is "Combined System," and the Institute "confidently recommend the adoption" of the system. Particular stress is laid on the elimination of the gully trap, which in the older system receives the discharge from all washing fitments. Incidentally, it is primarily the abolition of the gully trap, together with its attendant nuisances, that constitutes the new system.

Advice is given on grouping the fitments with the object of reducing the length of piping used. Proper accessible plumbing space is advocated for inside soil pipes, and that a suitable and efficient trap is to be fixed immediately beneath each fitment; the depth of water seal being 2 in. where the waste pipe is not less than 3 in., and 3 in. in depth where it is less than 3 in.

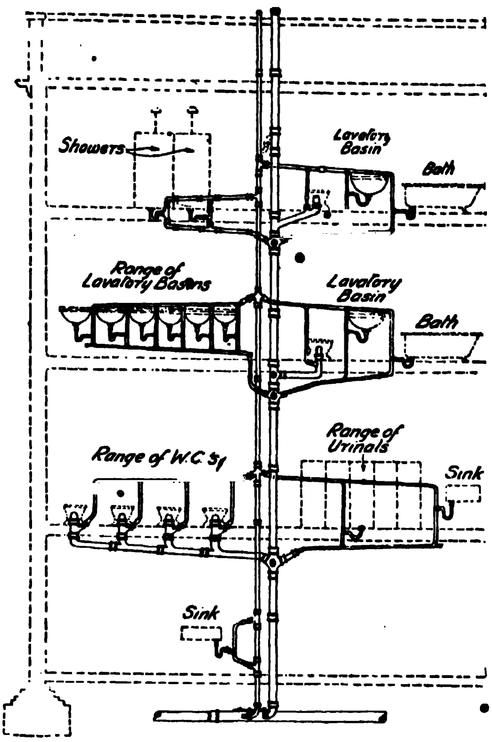
All traps, it is stated, are required to be ventilated into the open air. It therefore rules out all resealing traps, unless a ventilating pipe is installed. (For requirements concerning vent pipes *see under* the heading Anti-Siphon Pipe, page 53.)

There are a number of drawings given in the Specification which set out very clearly the general layout of various groups of sanitary fitments.

A four-storey building (Fig. 22) with a combined soil and waste pipe and main ventilating pipe is presented as a general example. The vent is connected direct to the iron manhole, and terminates at the same height as the soil and waste pipe. Note that the sink waste in the lowest storey connects to the ventilating pipe and not to the soil and waste pipe. The object is to ensure that the foot of the main ventilating pipe is flushed by the discharge from the sink and, therefore, free from drainage obstruction.

The next floor has a double loop system receiving four closets on one loop, and a range of five urinals, together with a sink on the second loop. In addition to the access cap on the junction, access is provided on the branch waste receiving the urinals to assist in clearing.

The floor above also has two loops; one receives a range of six lavatory basins which discharge into the lower junction. The second loop receives the discharge from a bath and



ONE-PIPE SYSTEM. Fig. 22. Composite layout for a building of four storeys on the "Combined System" of soil, waste and ventilating pipes, according to the Institute of Plumbers' Minimum Specification. *Redrawn from "Minimum Specification" No. 1 (1943) by permission*

lavatory basin ; the closet is taken into the main stack separately, and the trap ventilating pipes join the top part of the loop before it connects to the main ventilating pipe.

The top floor also has two loops ; one receives two shower fitments, while the second loop is similar to the one immediately below. The main ventilating pipe can return to the main waste stack above the top-floor fitments, as indicated by the inverted junction. The main stacks, and some of the branch wastes and vents are in cast-iron, while the remainder of the piping is shown in lead.

It is a very comprehensive layout and depicts very clearly the general principle of the system. Modification would, of course, be necessary, particularly where it is not desirable to show waste pipe work at ceiling level in the room below, and a false ceiling is impracticable.

Paragraph 4 of this section of the Specification deals with the ventilation of traps (Anti-siphon pipes) :

Ventilating of Traps (Anti-siphon Pipes). "The trap provided in connexion with every fitment should be ventilated into the open air at a point as high as the top of the ventilating pipe, or into the ventilating pipe at a point above the highest fitment connected with such pipe. The ventilating pipe should be connected at its lowest end in the direction of the flow, at a point below the lowest branch on the soil pipe, or to a suitable connexion in the inspection chamber at the invert level of the drain."

The sizes for ventilating pipes from such traps are as given in the Table in page 53.

If applied to a range of lavatory basins this Specification secures that the vent pipes from each basin are at such a height that they cannot under any circumstances be utilized as a waste pipe, in the event of the waste pipe being blocked. When the main branch vent pipe is fixed below the lavatory basins, as very frequently occurs, it is possible for the vent pipe to act as a waste pipe under the conditions quoted, with the possibility of blocking that portion of main branch vent pipe. Ample access is provided to clear the branch waste pipe if a blockage arises.

Lavatory basins and bathroom units are described in the Specification with diagrams. Loop venting, it is stated, "should be adopted wherever practicable."

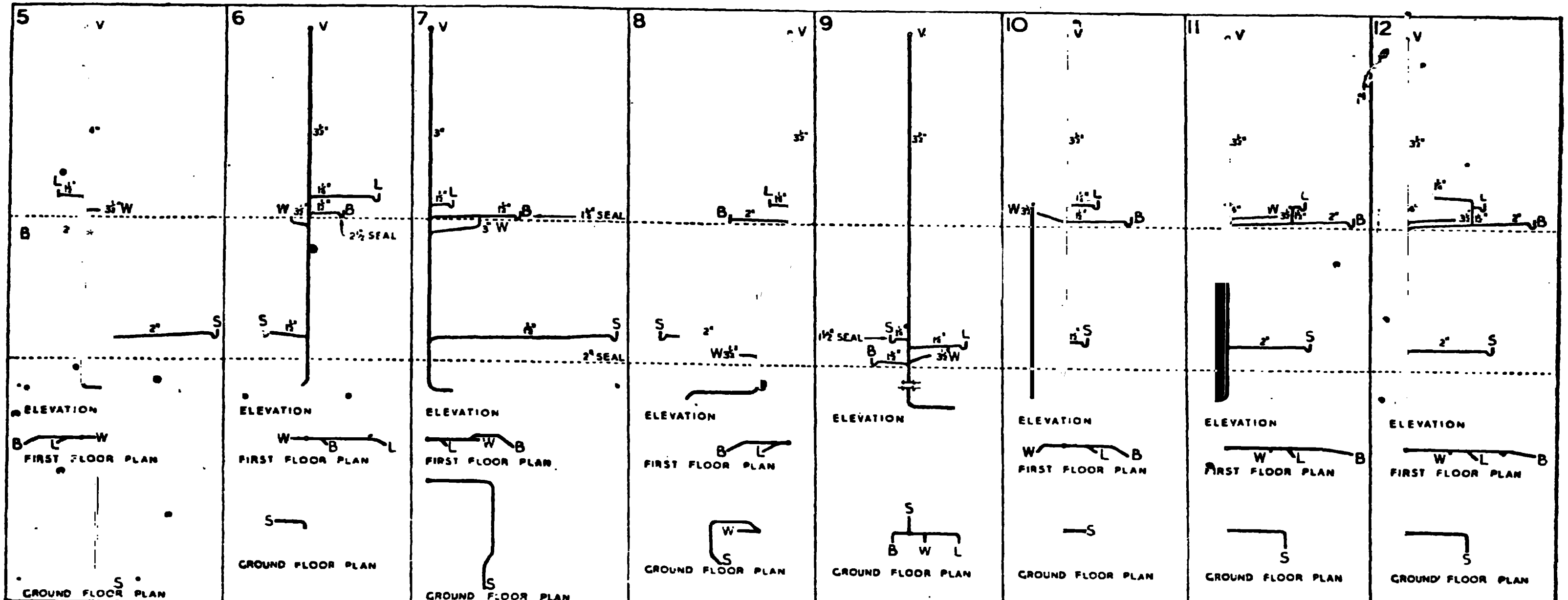
ONE-PIPE SIMPLIFIED, OR 'SINGLE-PIPE' SYSTEM

By F. C. Cook, M.R.San.I., M.S.I.A., R. P.

The Post-War "Building Study" No. 4, Plumbing (*see* Supplement to Vol. 3 of this work) devotes much space to the consideration, effectiveness and improvement of the One-Pipe system described in the preceding pages. The considerations of the investigators on the Committee, and the system they propose, which is referred to in the Report as "One-Pipe Simplified," or, as the writer prefers to call it, "Single-Pipe," are dealt with in this section.

Exclusion of Foul Air from the Building. It is stated that : "the disposal pipes should be so designed that the water seals in all the traps are maintained under all conditions likely to arise in practice."

Some difficulty is usually found in maintaining the water seal at the prescribed depth (By-Law requirement) under all conditions, a fact which can be appreciated when one examines the water seal of the



5

No.	Test A S	Test A L	Test A B	Test A W	Test B S	Test B L	Test B B	Test B W
1	1/8"	—	—	—	—	—	—	—
2	1/4"	1/8"	—	—	—	—	—	—
3	1/4"	—	—	—	—	—	—	—
4	1/8"	1/8"	—	—	—	—	1/8"	—
5	3/8"	1/8"	—	—	—	—	1/8"	—
6	1/8"	1/8"	—	—	—	—	—	—

6

No.	Test A S	Test A L	Test A B	Test A W	Test B S	Test B L	Test B B	Test B W
1	—	1/8"	—	—	—	—	1/4"	—
2	1 1/8"	1/8"	—	—	1/8"	1/8"	3/8"	—
3	3/8"	—	—	—	1/8"	1/8"	—	—
4	3/8"	—	—	—	—	—	—	—
5	3/8"	1/8"	—	—	—	—	—	—
6	3/8"	—	—	—	—	—	1/8"	—

7

No.	Test A S	Test A L	Test A B	Test A W	Test B S	Test B L	Test B B	Test B W
1	3/8"	1/8"	—	—	—	1/4"	—	—
2	1	1/4"	—	—	—	1/4"	—	—
3	1 1/8"	1/8"	—	—	—	1/8"	—	—
4	3/8"	3/8"	—	—	—	1/4"	—	—
5	1 3/8"	1/4"	—	—	—	1/4"	—	—
6	1 1/8"	3/8"	—	—	—	1/8"	—	—

8

No.	Test A S	Test A L	Test A B	Test A W	Test B S	Test B L	Test B B	Test B W
1	1/8"	1/4"	—	1/8"	—	—	—	—
2	1/8"	—	—	—	—	—	—	—
3	1/8"	—	—	1/8"	—	—	—	—
4	1/4"	—	—	1/8"	—	—	—	—
5	1/8"	—	—	1/8"	—	—	—	—
6	1/4"	—	—	—	—	—	—	—

9

No.	Test A S	Test A L	Test A B	Test A W	Test B S	Test B L	Test B B	Test B W
1	1/8"	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—
4	—	—	—	—	—	—	—	—
5	—	—	—	—	—	—	—	—
6	—	—	—	—	—	—	—	—

10

No.	Test A S	Test A L	Test A B	Test A W	Test B S	Test B L	Test B B	Test B W
1	—	—	—	—	1/8"	1/8"	—	—
2	1/8"	1/4"	1/8"	—	1/8"	1/8"	—	—
3	—	—	—	—	1/8"	—	1/8"	—
4	1/8"	1/8"	1/8"	—	—	1/8"	—	—
5	1/8"	3/4"	1/8"	—	1/8"	3/8"	3/8"	—
6	1/8"	1/2"	—	—	—	1/4"	—	—

11

No.	Test A S	Test A L	Test A B	Test A W	Test B S	Test B L	Test B B	Test B W
1	3/8"	3 1/8"	—	—	1/8"	2 1/2"	3/4"	—
2	3/8"	2 7/8"	—	—	1/8"	2 7/8"	3/8"	—
3	1/2"	3 1/8"	—	—	[illegible]	2"	1/4"	—
4	1/8"	[illegible]	—	—	1/4"	2 1/2"	3/8"	—
5	1/4"	3 1/4"	—	—	—	2 1/2"	3/8"	—
6	—	—	—	—	1/8"	2 3/8"	3/4"	—

12

No.	Test A S	Test A L	Test A B	Test A W	Test B S	Test B L	Test B B	Test B W
1	1/2"	1 3/8"	—	—	1/8"	3/8"	1/4"	—
2	3/8"	2 7/8"	—	—	—	—	1/8"	—
3	3/4"	2 1/8"	—	—	1/8"	1/8"	3/8"	—
4	3/8"	2 3/8"	—	—	—	—	1/4"	—
5	1/2"	1 1/8"	—	—	1/8"	—	1/8"	—
6	1/2"	1/8"	—	—	—	1/4"	3/8"	—

TEST A. "DRY SINK" TEST

1. Washbasin and bath filled to overflow. 2. 6 pieces of newspaper 8" × 6" placed in each closet pan. 3. Plugs removed from waste outlets and 2 gals. water tipped into each pan. 4. Pans flushed from cisterns immediately after discharge from buckets.

TEST B. "DRY BATH" TEST

As Test A, but reading sink for bath.

• ONE-PIPE SYSTEM. Fig. 23. Tests for siphonage of traps in simple One-Pipe installations, taken from "Building Study," No. 4, "Plumbing." This reproduction of part of the chart shows the 8 trials at London. Trials were also made at Coventry (1) and Birmingham (3) with not dissimilar results. In the drawings note that the elevations show developed lengths of branches and not their actual elevations. Waste seals are 3 in. except where otherwise stated. Dimensions shown at W.C. connexions give diameter of outgo. Each test was carried out six times. Figures in the tables below the drawings give losses of seal on trap.

From "Building Study" No. 4, "Plumbing." Copyright, H.M.S.O.

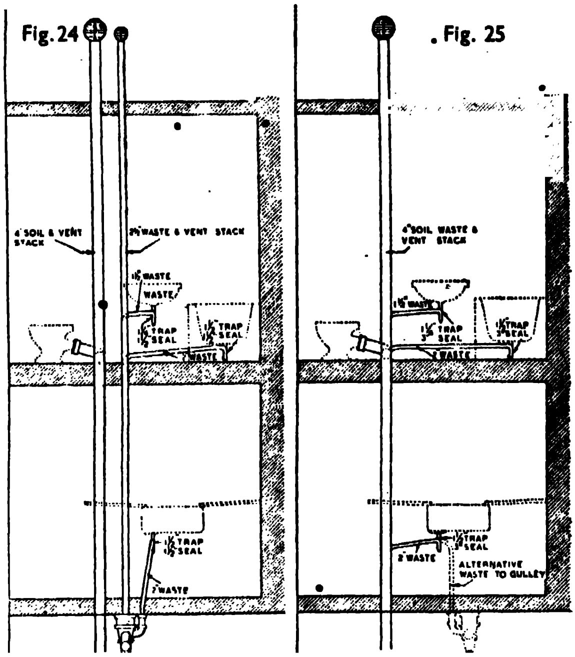
Reference

W. W.C. set
B. Bath
L. Wash basin
S. Sink
V. Vent.

water closet on a windy day and notes the oscillation of the trap water caused by the varying air pressure, resulting in some of the trap water waving out and so reducing the water seal.

The standard recommended in American plumbing is that with a 2 in. seal it shall not be reduced to less than 1 in. (Incidentally, the Ministry of Health Model By-Laws do not even require a trap to be fixed to a washing fitment waste pipe under 6 ft. in length, when it discharges into a gully. Under such conditions a steady flow of fouled air passes into the apartment, due to convection air currents set up within the waste pipe by a higher inside temperature of air than that prevailing outside.)

To obtain reliable data on this part of the subject, the Committee carried out full scale tests on bathroom fitments (with and without closets) and kitchen sink, using both one and two floors for the tests (Fig. 23 opposite).



ONE-PIPE SYSTEM. These drawings, from "Building Study" No. 4, compare the two systems—Fig. 24, Two-Pipe and Fig. 25, Simplified One-Pipe, or Single-pipe. In the simplified One-Pipe trap-ventilating pipes were omitted.
Copyright, H.M. Stationery Office

The principle involved was to adopt the "One-Pipe" system of plumbing which has been practised in the London area for over 14 years, and consists of combining the soil and waste pipe or connecting the waste pipe direct to the drain without the interposition of gully trap, and providing ventilating pipes to all traps (*see* pages 720-728).

Although this system has proved efficient and more economical than the two-pipe system (where waste water fitments discharge their contents into a foul gully trap, and the soil pipe discharges direct to the drain, as shown in Fig. 24) the Committee considered that further economy could be obtained by omitting trap ventilating pipes to the "One-Pipe" system, providing there was no loss of efficiency, thereby installing what is really a "Single-Pipe" system.

With this end in view plumbing fitments were installed, using various size pipes in both length and diameter ; 12 layouts were installed and submitted to abnormal tests, which consisted of discharging three of the four fitments simultaneously and noting the effect on the water seal of the fourth fitment and also of the fitments discharged.

It would appear from a careful study of the chart from the Report (Fig. 23), which displays details of 8 of the 12 tests, that the best results were obtained with the larger size vertical pipes, and also that branch pipes of large diameter are favoured. It will also be noted that P traps are used, and that the fall of the waste pipe does not exceed the depth of the trap seal, which, in consequence, renders self-siphonage impossible, seeing that the trap and waste pipe do not form a siphon.

The branch wastes of washing fitments are separately connected to the main stack, and not interconnected (except in two instances, when marked siphonage took place) thus obviating the action of siphonage by "aspiration" on the fitment trap not being used. To overcome this action on the branch wastes, when, say, a closet is discharged, it will be noted that the larger diameter vertical stack gives the best results. Also, less favourable results are obtained when the main ventilation pipe is of smaller diameter than that of the soil pipe (as shown in test No. 11 and No. 12 on the chart).

In No. 1 layout (not shown on the chart) a closet was installed on each of the two floors, and the test revealed large air bubbles passing through the trap

water of the lower closet, when the full test was made from the upper floor. This action indicated that compression of air was set up at the base of the stack and passed into the closet branch, since the trap water offered insufficient resistance to the air pressure.

Under these conditions it is safer to connect the lower closet to the manhole direct, although I am convinced that if the connexion to the drain is in the form of a long radius bend or bends, the frictional resistance will be negligible ; the governing factor on this point will be the depth of the manhole.

The abnormal tests previously mentioned consisted of the washing fitments being filled with water up to overflow level, 2 gallons of water tipped into the closet in which were placed 6 pieces of newspaper 8 in. by 6 in. and the contents of flushing cistern discharged simultaneously. These conditions are not likely to arise in ordinary use, and from enquiries made I learn that in normal use with the larger diameter pipe, no measurable loss was experienced.

The Committee's activities were confined to 2-floor buildings, but they propose to extend their experiments on similar lines to multi-storey buildings.

The general conclusions arrived at on this part of the Report are as follows :—

(*a*) Simple One-Pipe systems (Single-Pipe) for one or two-storey housing can be designed under practical conditions of use, without siphonage of traps in spite of the absence of special trap ventilation.

(*b*) The size of stacks and branches has a controlling influence on the liability of siphonage, the use of 4 in. stacks with 2 in. waste branches giving safer conditions than obtain with smaller stacks and branches.

(*c*) When the wash-basin is run directly to the common stack, it is much less liable to siphonage of its trap than when it is dropped vertically to the bath branch.

These conclusions appear to be sound, seeing that they are based on the experience gained by practical test, and I feel sure that the basic principles will be included in subsequent By-Laws. This will enable plumbing work to be carried out more economically and without loss of efficiency.

I supervised the installation in 1936 of a "Single-Pipe" system in a block containing 6 storeys, used as artisans' dwellings (Fig. 26A–C).

The stack, which was in 4 in. copper pipe, was situated at the head of the drain, which consequently discharged into a shallow manhole, necessitating a fairly sharp bend after connecting the lowest closet to the stack. Foreseeing that compression would be set

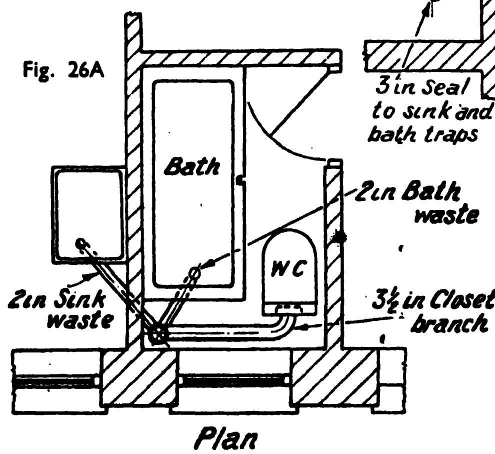


Fig. 26A

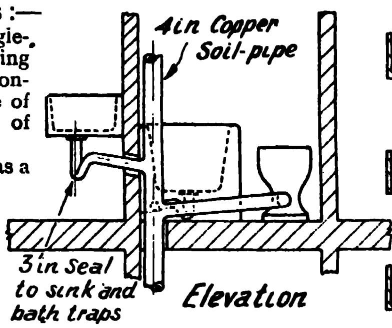


Fig. 26B

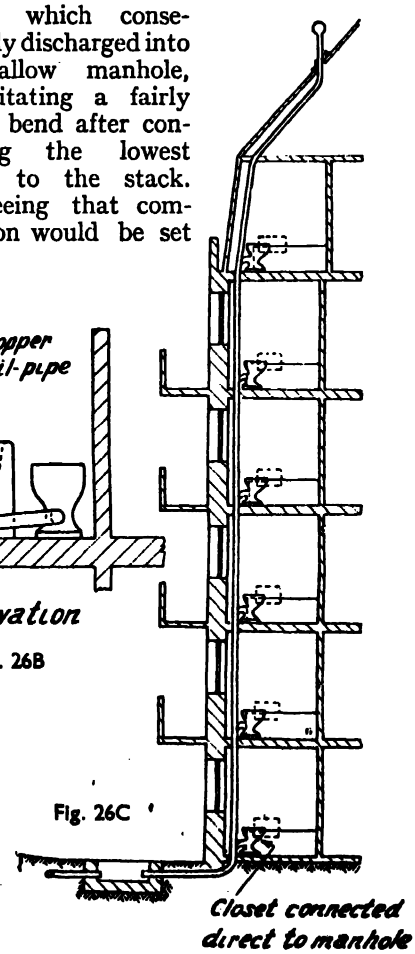


Fig. 26C

ONE-PIPE SYSTEM. Fig. 26A, B, and, C. Plan, elevation and section of a "Single-Pipe" system installed in a six-storey building in 1936, supervised by Mr. F. C. Cook (for details see text). The system gave no trouble and when inspected 12 years later showed under test ½ in. loss of seal in 2 closets and no measurable loss in washing fitment traps.

up at this closet, a branch drain was installed to receive it if required.

After repeated abnormal tests, it was found to have lost 1 in. of its 2 in. seal, due to compression, and was therefore connected to the branch drain. The bath waste connected to the stack on the same floor showed no appreciable loss, due to the resistance of a 3 in. water seal in the trap. The maximum loss of water seal to the closets on the upper floors was ½ in., which was considered satisfactory, while no measurable loss was found in the 3 in. seal traps of the washing fitments, the waste pipes of which were 2 in. copper.

I inspected the stack after it had been in use for 12 years, and measured the depth of seals of all the fitments, with the result that two closets showed ¼ in. loss of seal, and no measurable loss to the washing fitment traps; I was informed that the stack had given no trouble since it was installed 12 years ago and in constant use since.

The principle involved is not new and is provided for by implication in the L.C.C. Drainage By-Laws Sec. 10 (1) (*c*), and applies to waste water fitments which discharge into a gully trap, and reads as follows:—

> Ventilation to traps. In order to preserve the seal of the trap of any such fitment such trap shall be ventilated *whenever necessary* by a ventilating pipe . . .

Advantage is frequently taken of this section when installing blocks of flats up to five storeys in connexion with Housing schemes, using a 3 in. main waste pipe to receive the separate waste pipes fitted with 1½ in. seal P-traps and provided with a sluggish fall, and no trap ventilation pipe provided.

I have applied maximum tests to these systems and found negligible loss of seal, while with ordinary use there was no loss.

Seeing that the above installation is not only permissible, but sound from a hygienic standpoint (apart from its discharge into a gully, which is always in a fouled condition, and from which foul odours must arise) and that only 1½ in. seal trap need be fixed, the following consequences arise.

It would appear logical reasoning to remove the foul gully, connect the stack direct to the drain, and, as an extra factor of safety, install 3 in. seal traps to the washing fitments, thus providing additional resistance to the action of aspiration. By this method, the cost of the ventilation pipes, their installation and maintenance is saved, no loss of efficiency results and a more hygienic system is installed.

The existing L.C.C. Drainage By-Laws require ventilating pipes to all traps of waste water fitments if the gully trap is omitted and the waste pipe connected to the drain. I have shown that they serve no useful purpose so far as maintaining the seal is concerned, unless the waste pipes from two or more fitments interconnect to the branch waste pipe; then trap ventilation is necessary in order to maintain the seal. The By-Law requirement reads:

> Sec. 10 (2) (*b*) II. . . . be ventilated in the manner prescribed in By-Law 9 for the ventilation of trap of soil fitment.
>
> By-Law 9 (1) reads: . . . the trap of every such soil fitment or waste water fitment shall be ventilated.

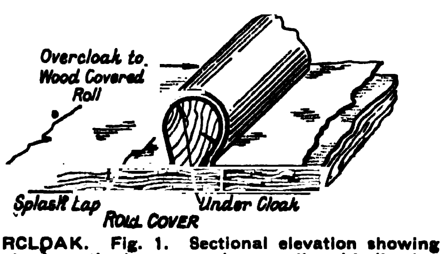
It would appear, therefore, that in order to install the Single-Pipe system legally, the provisions of the By-Laws must be altered, and extended, so as to include the system. Consideration was (in 1949) being given for its inclusion in the revision of the L.C.C. By-Laws on Drainage.

ONE-PIPE SYSTEM: Heating. Principle of hot water heating in which a single pipe circulation is used in mains and branches. Radiators have both their service connexions into one pipe; hence distinctive name. *See* Heating: (2) By Hot Water.

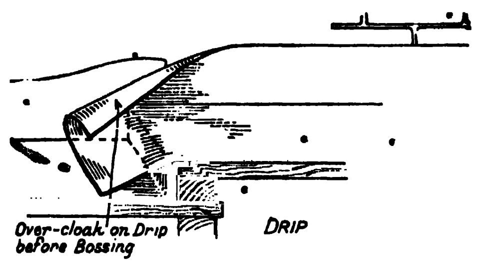
OVERCLOAK. The "over-lay" or "passing" in a weathering of sheet lead in roof coverings. It is the top piece of lead passing over the lead below, as for instance the top cover on a lead roll or a drip. The term is used where bossing or working is required, rather than with a plain "lap" or passing. The passing below is the "undercloak" (*See* Figs. 1-3).

The overcloak protects or weathers the plain edge of the under lead.

Considerable skill is required to work the lead of drips without unduly stretching the sheet in the internal angles.



OVERCLOAK. Fig. 1. Sectional elevation showing sheet-lead weathering to wood core roll and indicating undercloak and overcloak.



OVERCLOAK. Fig. 2. Overcloak to drip ready for bossing into the shape indicated by dotted lines.

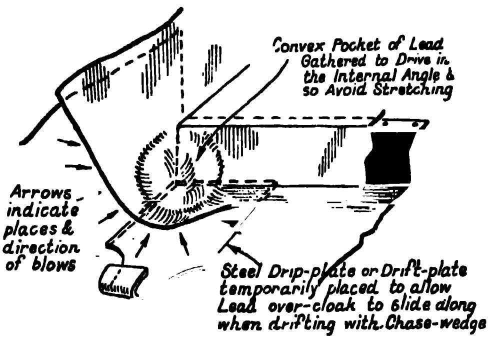


Fig. 3. Overcloak to drip nearing completion, showing convex lead pocket and steel drift plate in position for working.

Unskilled or unpractised workmen often produce what is known as a "cock's-eye" —*i.e.* a small tear in the corner. The same degree of skill is required to work the lead home on the overcloak of a roll abutment to a vertical wall (Fig. 4) or to a drip.—*A. C. Martin, M.R.San.I., R.P.*

See Drip ; Gutter ; Roofwork in Lead.

OVER FLASHING. Term applied to any piece of cover flashing. *See* Flashings.

OVERFLOW. Overflows to modern lavatory basins and sinks are cast or otherwise made as an integral part of the fitment and should consist of a glazed tube, or pipe, leading from the inside of the basin or sink at a height at which the water can overflow without flowing over the top edge, to a position between the top and bottom of the waste hole. This overflow tube should be of sufficient size to carry away the discharge from valves over the basin or sink when running together at their maximum capacity.

It is obvious that with the mouth of the overflow in such a position, soapy and greasy matters floating on the top of the water will flow over into it. These matters will cling to the side of the overflow, there to accumulate and eventually block the pipe unless the overflow is cleansed.

To avoid this trouble, the overflow to such fitments should be open to view,

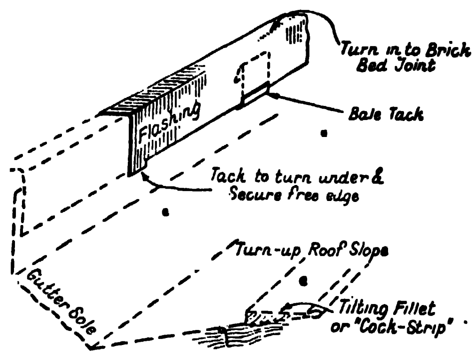


Fig. 4. Overcloak in flashing (with undercloak indicated by dotted lines) as used to provide watertight side of gutter. Overlap is in direction of flow.

readily accessible for cleansing, and large enough to admit a cleansing appliance. In a large number of kitchen sinks still being fitted, the inadequate access for cleansing gives rise to smell and other nuisance.

When fixing the brass waste fitting see that the hole in the fitting is large enough and free, and that any material such as red and white lead used for bedding-in the waste is kept clear of the overflow hole.

Baths. The provision of an overflow to a bath in the same manner as described above (that is, to provide an overflow pipe so that the water discharges into or above the water seal of the trap) is not eminently satisfactory, on account of the difficulty of access for cleansing purposes. However, combined standing waste and overflows to bath are still provided. Another method often adopted is to connect the bath overflow union to the bath trap with a short piece of lead pipe.

The overflow from a bath or, for that matter, a sink or lavatory basin, must not enter a waste pipe on the outlet side of the trap.

The By-law of the Metropolitan Water Board in respect to overflow pipes from baths, basins and sinks is as follows :

54. *Overflows of Baths, Lavatory Basins and Sinks.* [Every overflow pipe] provided in connexion with a bath, lavatory basin or sink, shall be so fixed that its outlet, or the outlet of any waste pipe with which it communicates, shall, where practicable, be in an exposed and conspicuous position where the discharge of water may readily be seen.

while the amendment to the above By-law reads :

[An overflow pipe or waste pipe which is connected directly with a sewage drain or sewage drain ventilating pipe or the soil and waste pipe or ventilating pipe of a water closet, slop sink intended for receiving solid or liquid filth, or urinal]

This amendment takes into consideration cases where baths, sinks and lavatory basin wastes are discharged into a soil pipe or drain, in which case a visible end is not possible. In such cases the Board are compelled to rely on the visible inlet provided for in By-law No. 52 as the only check on waste of water.

Overflow pipes provided to baths, water waste preventers and storage cisterns should in each case be of sufficient diameter to carry away the discharge from the point of supply when running at its maximum capacity. If this rule is not adhered to and a smaller pipe is provided, serious results may ensue from flooding should the water be left running in the case of the bath, or a washer fail in the case of the ball valves.

Warning Pipe. To each of these fitments a projecting overflow pipe must be provided as a warning pipe; care should be taken that damage to persons or property is not likely to arise by a discharge therefrom.

The Metropolitan Water Board By-law definition in respect of these overflows reads:

Warning Pipe. An overflow pipe so fixed that its outlet is in an exposed and conspicuous position where the discharge of any water may readily be seen and where practicable, outside the house or building.

and with special regard to cold water cisterns the following by-law is quoted:

53. *Overflow Warning Pipes.* Every cold water cistern shall be provided with an efficient warning pipe and with no other overflow pipe.

In regard to the size of an overflow pipe, the M.O.H. Model Specification reads that every flushing cistern shall be provided with a warning pipe of not less than ¾-in. diameter. This stipulation is repeated in the Minimum Specification of the Institute of Plumbers, which requires that a warning pipe or overflow pipe should not be less in internal diameter than ¾ in. Where the inlet pipe to the cistern is of an internal diameter of ¾ in., or over, the warning pipe or overflow pipe should be at least one size larger than the inlet pipe.

With regard to the height in the cistern or tank at which the overflow should be fixed, the specification reads that the centre of the pipe should be at least 1½ in. below the centre of the ball valve. In no case should the overflow be fixed above the level of the inlet pipe.

Hinged copper flaps fixed to the external ends of overflow pipes, especially those of large diameter, will prevent the ingress of birds and debris; and, in the case of bath overflows, will prevent a draught of cold air being drawn into the pipe to cause discomfort to the bath user. —*W. J. Woolgar, M.R.San.I.*

See Bath; Cistern; Sink; *also* Metropolitan Water Board; Model By-laws.

OVERHEAD SYSTEM (Heating). System in which the pipes or pipes and radiators are placed overhead instead of at or near the floor.

Many buildings—especially of the factory type—are heated by overhead pipes or radiators, an arrangement giving clear floor space which is sometimes valuable; but the modern factory structure is not suitable for this type of heating, as the warmth is prone to remain at a high level. If heating surface must be fixed overhead, fans should be installed to blow the warm air down towards the floor. Hence the use of Unit Heaters (*which see*).

Overhead systems are sometimes carried out with pipes or flush radiator panels fixed in ceilings, and the warming of the rooms is effected by radiation only; but in this case it has been found best to place also some heating surface at or near the floor line.

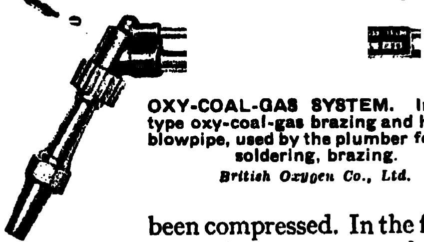
Gas-heated panel and radiant heaters are frequently placed overhead (*see* Gas Fires; *also* Radiant Heating).

Overhead Pipe System. The term overhead system is also applied when, in order to obtain a good circulation, the main flow and distributing pipes are carried overhead with dropping pipes to feed radiators which may be at the same level as the boiler.

OXY-ACETYLENE SYSTEM. *See* Welding: (1) Oxy-Acetylene Process; *also* Acetylene; Fusion (Flame) Cutting; Lead-Burning.

OXY-COAL-GAS SYSTEM. For any welding, brazing or soldering processes it is necessary to have a localized source of heat. In the oxy-acetylene process (*see the heading* Welding) it is the acetylene which supplies the heat. For some purposes, however, the high temperature of the oxy-acetylene flame (which has been computed to be about 3,500° C.) is too intense. Accordingly, other fuel gases have been adopted. Of these one of the most important is coal-gas.

The oxy-coal-gas system may be used for the cutting of metals, for brazing and for soldering, but not for welding. The coal-gas may be taken either from the mains or from cylinders into which it has



OXY-COAL-GAS SYSTEM. Injector type oxy-coal-gas brazing and heating blowpipe, used by the plumber for hard soldering, brazing.
British Oxygen Co., Ltd.

been compressed. In the former case it is necessary to have a non-return valve attached to the mains; whilst in the second case a pressure regulator must be attached to the cylinder. In both cases the equipment necessary is similar to that for the oxy-acetylene process; *see* therefore *under* the headings Acetylene *and* Welding.

The oxy-coal-gas system utilizing coal-gas from a cylinder resembles the high pressure oxy-acetylene system. When the coal-gas is taken from the mains, the system resembles the low pressure oxy-acetylene method, but it is not necessary to have a hydraulic valve for coal-gas.

A typical oxy-coal-gas brazing and heating blowpipe is shown above. It is of the injector pattern, and may be used for general coppersmith and plumber work; also for brazing and hard-soldering.

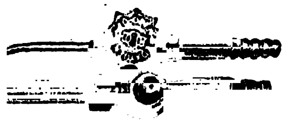
The oxy-coal-gas system has also been used extensively for lead-burning; *see under* the heading Lead-burning.

The greatest advantage of coal-gas is that it is very cheap. The disadvantage is that the source of heat is not so localized, and accordingly jobs take longer when coal-gas is used.—*N. F. Daniel, B.Sc.*

See Oxy-Hydrogen System.

OXYGEN. Oxygen when used in conjunction with a suitable fuel gas, such as acetylene or coal-gas, is the most important gas for welding, cutting and brazing metals. It is supplied to the trade in steel cylinders under a pressure of 120 atmospheres. It is manufactured by first liquefying air and then distilling off the nitrogen. The liquid oxygen so formed is then gasified and compressed into cylinders. The purity of commercial oxygen has reached a very high standard. The gas usually available is about 99·5 per cent. pure. The impurities are mainly nitrogen and argon, both of which gases are inert.

Oxygen cylinders most commonly used in industry are 100, 150, and 200 cu. ft. Smaller and larger sizes up to a capacity of thousands of cubic feet are also available.



For steelworks, foundries, shipyards, engineering workshops, etc., supplies are usually made in the liquid form to a liquid oxygen evaporator. From it pipelines run to points of consumption so that oxygen for welding or cutting is available "on tap." This obviates the transport and storage of large quantities of oxygen cylinders.

Compressed oxygen is a strong supporter of combustion. No grease or oil should be allowed to come into contact with it.

Valves, stopcocks, pressure gauges, etc., should never be lubricated or there will be danger of ignition, or even explosion.

Again, oxygen should never be used in place of compressed air for removing grit or dirt from pipes, tubes or fittings; nor should it be inhaled as a stimulant. Inhalation has caused fatal accidents.—*N. F. Daniel, B.Sc. See* Air; Welding.

OXY-HYDROGEN SYSTEM. Method of brazing or soldering in which hydrogen is used as the fuel gas. The hydrogen may be generated on the site (low pressure oxy-hydrogen system), or it may be taken from cylinders (high pressure hydrogen). If made on the site a small generator is necessary: the hydrogen is made by the interaction between dilute sulphuric acid and zinc spelter. In the high pressure system hydrogen is taken from steel cylinders under a pressure of 120 atmospheres.

In details the low pressure and high pressure oxy-hydrogen systems are similar to low pressure and high pressure oxy-acetylene systems respectively.

Hydrogen is rarely used for brazing or soldering, its principal application being for lead-burning. The great advantage of it is that it gives a very small, very clean flame. The flame is easy to manipulate, and is admirably suited for intricate work. Disadvantages are that if the compressed hydrogen is used it is expensive; while if generated hydrogen is used the equipment is messy and inconvenient.—*N. F. Daniel, B.Sc.*

See Acetylene; Lead-Burning; Oxy-Coal-Gas System; Welding.

PANEL HEATER, Electric. Heaters in which the heating elements are hidden behind flat sheets of metal or panels. Term is usually applied to low temperature heaters from which the emission per sq. ft. of heating surface is low.

The ideal temperature for panel warming is about 100°F., but such a large area of panel would be required that it is usual to effect a compromise and work at a temperature of 180°F. to 200°F., which corresponds to a surface loading of approximately 100 watts per sq. ft.

It is usual to fit the elements in shallow boxes of sheet metal, the front of which forms the emitting surface ; occasionally, however, cast-iron boxes are used. The front panel may be mounted flush with the wall or ceiling—a very neat construction ; or the heater may be mounted on the surface, a method which can be applied with little effort. Several panels may be mounted side by side, so as to build up a large heating area.

Position for Heaters. The actual position of the heaters in the room is of the greatest importance, because on this depends the relative proportions of radiant and convected heat. Panel heating is intended to heat by low temperature radiation (*see* Radiant Heating), and consequently the position of the heaters should be so chosen that the convection losses are kept to a minimum ; obviously, this position is in the neighbourhood of the ceiling. There are bound to be convection losses even here, due to the circulation of ventilating currents ; but, nevertheless, if the surface of the panel is flush with the ceiling or even sunk below it, the convection losses are small.

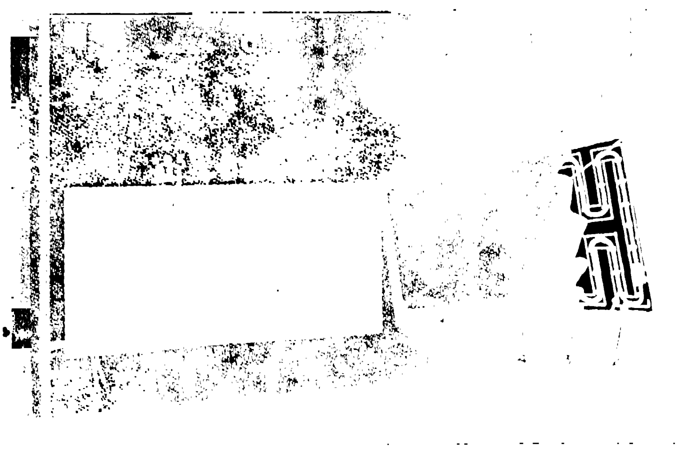
Tests by reputable authorities have shown that this is by far the most efficient method of heating a room, showing an advantage over other methods of about 25 per cent. Many people, however, object to heat rays striking them from directly overhead, and for this reason frequently a compromise is effected by mounting the heaters about three to four feet above the level of the floor, where the heat rays are not screened by furniture.

As the panels depend for their effect on radiation, the way in which they are finished is of great importance. The panels should not be of polished metal or be finished with metallic paint, as these finishes retard radiation. But, apart from this, the panels may be finished to tone with the decorations of the room.

Panel heaters have only one effective surface, and loss of heat to the walls should be prevented by interposing a layer of heat-insulating material, such as cork or some proprietary material, about one or two inches thick, between the back of the heater and the brickwork.

Even so, the effect of panel heaters is to raise the temperature of the walls slightly above that of the surrounding air, with the result that conditions of comfort can be obtained with a lower air temperature than would otherwise be the case, and the further result that stuffiness is avoided. Windows normally are at a temperature not far removed from that prevailing outside, and may in cold weather produce a feeling of chilliness and feeling of discomfort in that side of the body which faces them ; but they will reflect heat from panel heaters favourably placed.

Panel heaters are sometimes fitted low down in the wall, but in this position there is considerable convection loss and they correspond to a low temperature



PANEL HEATER. Fig. 1. "Braby" all-steel panel heater ; showing angle-iron frame and waterproof back in position, and front plate (containing element) ready to be fixed : (1) rolled steel plate ; (2) refractory material encasing nickel-chromium heating element ; (3) mica strips for extra insulation ; (4) special insulation to prevent heat loss from panel back ; (5) galvanized sheet boxed around angle of frame to isolate elements.
George O'Kill & Co., I

"radiator" (or, more correctly, a convector). They are, however, slightly more efficient than this form of heater, because none of the heat rays are screened. Occasionally panel heaters are sunk in the wainscoting or even in the floor; in these positions they correspond to tubular heaters.

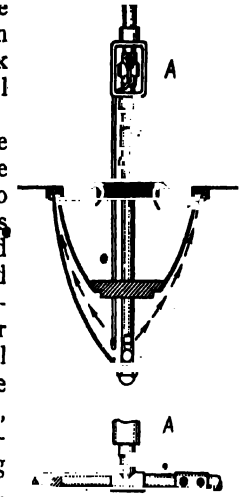
It is, of course, a common practice to place heaters underneath windows so as to prevent the down-draughts that would otherwise be caused. This practice should still be followed when a large room with large areas of window has to be heated. Panel heaters fitted in the ceiling or high up round the walls would be supplemented by smaller panel heaters (or preferably by convectors) placed under the windows.

For ideal conditions it is an advantage to fit a high temperature radiator or fire as well, to supply a visible radiant source, which has a beneficial effect both mentally and physically. But such elaboration is expensive and can be employed only when cost is not the first consideration.

Panel Radiator. There is another form of panel heater, known as a panel radiator. This type operates at high temperature, and is usually mounted or suspended at ceiling height, being inclined slightly downwards. The chief use of these, which are not properly regarded as "panel heaters," is for intermittent heating (in bathrooms, for instance), or where air changes are comparatively frequent (as in shops, the loggias of road-houses or in open air schools). They are not suitable for continuous warming indoors, because high temperature radiation from overhead can be distinctly unpleasant if prolonged. -*R. A. Baynton, A.M.I.E.E. See* Heating (4); Radiator, Electric.

PANEL HEATER (GAS). Low temperature panels, heated by hot water from gas-fired boilers have been in use for some years, and at the other extreme there have been high temperature panels, radiating heat from a visible red-hot source. To-day there is available an effective compromise between these two types—in the form of the high temperature black radiant panel heaters.

These heaters are available in three forms, designed to serve various sets of conditions, and they may be fixed to the wall or ceiling. Each heater has an external radiating surface at about 650° F., the radiant efficiencies varying from 40 per cent. to 48 per cent.



PANEL HEATER: Gas. Fig. 1. High temperature overhead radiant panel-heater. Gas is ignited by pilot jet after passing control cock and throttle. Products of combustion ascend as shown by arrows, escaping from outlets. A. Detail of cast-iron stirrup piece containing control cock.

1. (*a*) Rectangular panel, wall fixing, giving a forward distribution of heat.
(*b*) Rectangular garage panel, wall fixing, giving a forward distribution of heat.
2. Overhead bowl, ceiling fixing, giving a uniform heat distribution.
3. Overhead wedge, ceiling fixing, giving a non-symmetrical distribution.

The most used model is probably the wall fixing rectangular panel; this comprises an outer casing of sheet metal which can be fixed by brackets to the wall. Set into this casing is a thick refractory brick of low heat conductivity, while positioned at the base of the brick is a luminous burner made up of a number of Bray jets. In front of the burner and the brick is a vitreous enamelled iron plate held by a chromium-plated frame.

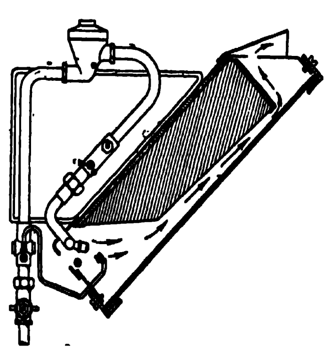
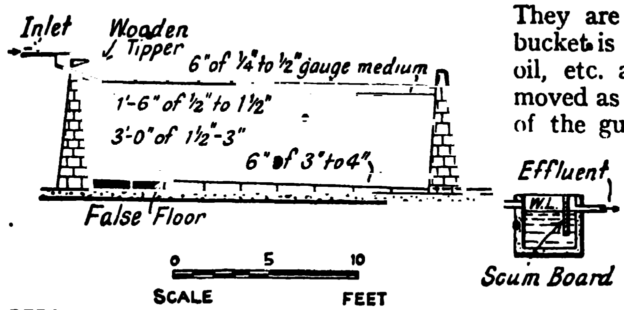


Fig. 2 High temperature radiant panel-heater, wall pattern. Gas is ignited by pilot after passing inlet and switch cocks, governor, and pressure control screw. Products of combustion escape as shown by arrows.

The products of combustion pass between the brick and the inside of the front plate, but the space is tapered so that the maximum heat is transmitted to and re-radiated from the front.

A governor controls the gas rate and standard models have a wire cable remote switch control. The gas rate of all units is 25 cu. ft. per hour, 500 c.v. gas.—*J. Murray Grammer, A.M.Inst.GasE. See* Gas Fires.

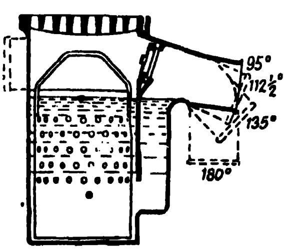
PANEL HEATING. *See* Radiant Heating. Panel Heaters are described in the preceding article.



PERCOLATING FILTER. Filter for "bacterial" purification of liquid sewage. Sewage percolates through porous layers to underdrains and is purified in the process.

PERCOLATING FILTER. A filter or bed constructed of layers of hard porous material such as clinker, over the surface of which liquid sewage, from which the large solids have been removed, is fed intermittently and distributed as evenly as possible. In percolating through the filter the liquid is purified by the oxidation of the putrescible sewage matter to stable compounds, through the agency of bacteria which live in a jelly-like film formed round the pieces of filtering material. The purified liquid flows out of underdrains laid beneath the filtering material. The term "percolating" distinguishes this type from the Contact Filter (*which see*). (*See also* Sewage Treatment.)

PETROL INTERCEPTOR. Intercepting chamber installed in a garage drainage system to prevent petrol and oil from reaching the local sewer. For a large garage a chamber of the type shown in Fig. 2, page 456 (*under heading* Garage Drains) would be built. In a smaller establishment where, for example, one or two cars only are garaged, interception of petrol, oil and grease can be provided for by the installation of a deep-seal gully with a perforated bucket (*see* Fig. 1, page 456). This last has access cover at top. Another pattern (shown here) has access cover inside. These gullies have a very deep trap, which assists in intercepting oil and petrol. They are made in various sizes. The bucket is filled with coke, which traps the oil, etc. and is afterwards burnt or removed as trade refuse. Another function of the gully or chamber is to hold back any grit or similar matter removed from the underside of the cars in washing them. *See* Garage Drains.



PETROL INTERCEPTOR. Garage gully, "H.M.O.W." pattern for interception at small garages. Access cap inside, fitted with gunmetal seating and screwed cap. Made 24" or 30" deep with 4" outlet; and 30" deep with 6" outlet.
(*Burn Bros., Ltd.*)

PETROL PIPES. Petrol, on account of its volatility and high degree of inflammability, is perhaps the most troublesome of all liquids for which pipes are employed. The special requirements in the way of jointing, etc. are explained in the article Pipes and Pipe Jointing (4), Section *A*.

PEWTER. An alloy composed of a basic part of tin with varying small quantities of lead, antimony, copper, and sometimes zinc, according to the type of alloy and its purpose. Pewter is a soft and ductile metal, silvery grey in colour. It is used in the form of sheet in the lining of sinks and counter tops, or may be cast into utensils or ornaments.

The composition of different qualities of pewter, in percentages, is as follows:

Tin	Antimony	Copper	Zinc	Lead
91·5	6	1	—	1·5
88	8	2	—	2
85·5	7	2·5	3·5	2·5

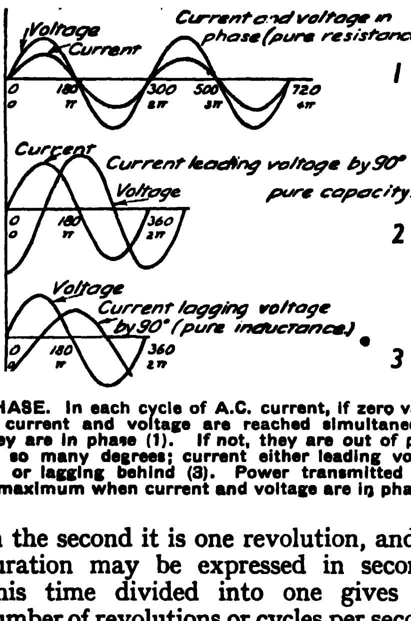
Pewter melts at a temperature of about 400° F., but if bismuth is added the melting point is lowered. Increase of copper and antimony hardens the metal.

Solders for Pewter. The most used compositions are:

Parts			
Tin	Lead	Bismuth	Melting Point In deg. F.
1	—	1	280
3	1	—	330
2	—	1	340
1	2	1	380

The fluxes used in soldering pewter are chiefly Gallipoli oil, tallow, resin and zinc chloride. On account of its low melting point the metal must be dealt with carefully and overheating prevented.

PHASE. This term means a stage or aspect of a cycle. An event that takes place at regular intervals is said to be "periodic" or "cyclic." Thus, Christmas Day falling on the 25th December each year, and the passing of a crank through top dead centre in each revolution are examples of periodic happenings. When a series of events repeats itself at regular intervals the events are said to be obeying or following a periodic law or function. The interval that elapses between the repetition of exactly similar events is called a cycle; thus, the length of the cycle in the first example is one year.



PHASE. In each cycle of A.C. current, if zero values of current and voltage are reached simultaneously they are in phase (1). If not, they are out of phase by so many degrees; current either leading voltage (2) or lagging behind (3). Power transmitted is at maximum when current and voltage are in phase.

In the second it is one revolution, and its duration may be expressed in seconds. This time divided into one gives the number of revolutions or cycles per second.

If two or more series of events are happening simultaneously and similar events in the different series happen at exactly the same time, the series are said to be "in phase"; alternatively, if they do not happen at the same time the series are said to be "out of phase."

The difference in phase may be expressed as a time interval, but in electrical and mechanical engineering it is more usual to give it as an angle. For instance, imagine two cranks on the same shaft, one at right angles to the other. In making a complete revolution, each crank will pass through 360 deg., but one crank will pass through a given point in the cycle (say top dead centre) a quarter of a revolution (or 90 deg.) after the other, and is said to be 90 deg. out of phase with the other. The crank that passes through a given position *after* the other is said to "lag" behind the first; conversely the first crank is said to "lead" the other.

Alternating Current. An alternating current obeys a periodic law. Starting from zero it gradually increases to a maximum in one direction, and gradually declines to zero; then it flows in the opposite direction along the conductor, gradually increasing to a maximum and finally falling away to zero again. This cycle of events is repeated as long as current continues to flow. If a graph is drawn showing the value of the current at any time plotted vertically against a time base, with current flowing in one direction along the conductor shown above the line, and current in the opposite direction below the line, a similar curve is obtained, which indicates the length of the cycle. For a 50-cycle supply this is 1/50th second; it is also 360 electrical degrees. Alternating voltage behaves in the same way, and may be similarly represented.

In Fig. 2 it will be seen that the voltage curve is passing through zero when the current is at a positive maximum; the phase difference is 90 electrical degrees. It could, of course, have any other value, depending on circumstances.

In that second example the current wave reaches a maximum before the voltage wave, and consequently leads it. If an alternating voltage is applied to a pure resistance (*e.g.* an electric fire), current keeps in phase with voltage, passing through a maximum at the same time as the voltage and so on (Fig. 1). But if it is applied to an inductance (Fig. 3) *e.g.* a choke coil, the current lags behind the voltage (by 90 deg. for a pure inductance); on the other hand, if it is applied to a circuit containing capacity (a bank of condensers, or lightly loaded cable) the current leads the voltage (Fig. 2).

For three-phase supply the generating machinery is so designed that the voltage in each supply cable is exactly 120 deg. out of phase with the voltage in the others.

When current is out of phase with the voltage, less work is obtained from a given current and voltage than if they are in phase; expressed in another way, for a given amount of work a larger current is required. In the same way

it requires a greater force to drag something along when the pull is at an angle than when the pull is straight. Larger currents call for larger supply cables, and that is why most supply authorities encourage their consumers to keep their current in phase with the supply voltage, by offering preferential rates or tariffs for so doing.—*R. A. Baynton, B.Sc., A.M.I.E.E.*

See Electricity.

PILLAR TAP. A tap having a tubular vertical inlet in the form of a pillar. These taps are made on the screw-down principle for ordinary use, and with a cam action for use in schools, institutions, etc. The object of the latter type is to avoid waste of water, as the tap is self-closing and is adjusted to suit the pressure of the water at the points where it is to be fitted.

The screw-down type is fitted with capstan heads and operated in the same manner as an ordinary bib tap. Both types are fitted with unions for connecting to lead or copper pipes ; connexion may be made to iron by means of the threaded tail piece. The latter vary in length according to the thickness of the fitting through which they are to pass. The discharging nozzles of pillar taps also vary in length to suit the distance from the opening in the fitting to the edge of the bowl, basin, sink or bath, as the case may be.

Like other water fittings the taps must conform to the standard laid down as regards the material, valve, test pressure, etc. *See* Metropolitan Water Board ; *also* the main article : Taps.

PIPE & PIPE FITTINGS: (1) LEAD PIPES

By E. J. F. Tillier, A.R.San.I., R.P.

This article briefly describes the process of making lead pipes, traps and bends. Tables of standard sizes and weights from appropriate B.S.S. and of other common sizes and weights are given. The sections are : A, Early methods of manufacture ; B, Modern methods of manufacture and merchanting ; C, Traps, bends, etc. ; D, Joints and jointing. See Lead ; Joints ; Pipework.

PIPE AND PIPE FITTINGS : (2) Brass and Copper Tubes
By A. L. McMullen.
PIPE AND PIPE FITTINGS : (3) Jointing of Brass and Copper Tubes
By A. C. Martin.
PIPE AND PIPE FITTINGS : (4) For Gas
By J. W. Cowan.
PIPE AND PIPE FITTINGS : (5) For Petrol, Oil and Compressed Air
By J. W. Cowan.
PIPE AND PIPE FITTINGS : (6) Iron and Steel Pipes for Hot Water and Steam
By L. C. C. Rayner.
PIPE BENDING
By Percy Manser.

Associated articles of importance which follow certain smaller articles in alphabetical order are :

PIPE-SIZING : (1) For Hot and Cold Water Supply Services
By W. E. Fretwell.
PIPE-SIZING : (2) For Gas
By J. W. Cowan.
PIPEWORK : (1) Water Pipes in Lead
By E. J. F. Tillier.
PIPEWORK : (2) Iron, Steel and Copper Tubes
By J. W. Cowan.

Other articles which must be consulted are those in the Heating and Hot Water Supply groups ; Rainwater Pipes ; Soil and Waste Pipes. Specialized information is given also under the headings Factory ; Flat ; Hospital ; Hotel.

The use of lead pipes for the conveyance of water dates back for many centuries, and discoveries in ancient Roman and Egyptian cities prove that lead pipe was extensively used. Even in Britain, the Romans during the period of occupation made abundant use of this metal, and examples of their skill are even now in existence (*see* the Introduction to Vol. I).

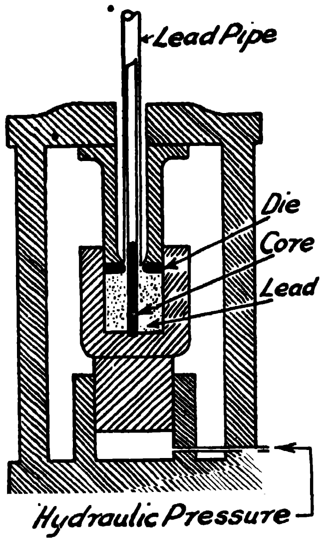
A. EARLY MANUFACTURE

The ingenious method employed by ancient craftsmen in making these pipes consisted of casting a flat sheet of lead in a sand mould of sufficient width for the required pipe size ; the flat sheet was then bent to form the pipe, and the two edges joined by pouring on molten lead previously heated to dull red-heat.

The pipe had to be filled with sand, and the outside entirely covered with sand except for the edges to be joined. The effect of this operation was to melt the two edges of the lead, and form an "autogenous" joint. A bead of metal was generally left along the joint or seam, this providing additional strength to what was, undoubtedly, the weakest part of the pipe. Sand or clay was used to form a mould during the joining process.

By the 18th century many different methods had been employed in making lead pipe, one of which was the use of solder in joining the two edges. This proved unsatisfactory in many cases, owing to fractures resulting from unequal expansion of the pipe, and due to the introduction of a harder and less elastic metal at the seam.

Towards the end of the century, owing to the increased demand for lead pipes, machines were rapidly being developed with the object of improving on methods which were at that time crude and laborious. It was also realized that the manufacture of pipes without seams would be far superior in every respect, and efforts were being made to produce a suitable machine for this purpose. It was at the beginning of the 19th century that the present process of "pressing" or "extrusion" originated. Since that time the presses have been improved in many ways, but the principles of the operation remain the same to-day.



PIPE : LEAD. Fig. 1. Section of lead press for pipes, showing lead in container.

B. MODERN METHODS OF MANUFACTURE AND MERCHANTING

The extrusion process was made possible by the invention and perfecting of the hydraulic press, which enables immense pressures to be used safely and conveniently, in easily controlled apparatus. The principle of the press is explained in pp. 593–4, under the heading Hydraulics. In the machine for extruding lead pipes the container for the lead virtually forms part of the ram of the press and moves up with the ram as pressure is applied beneath. Since the top member (incorporating the die) is stationary, the lead is constrained to pass up between the core (*see* Fig. 1) and the wall of the die and to take a tubular form.

Molten lead is introduced into a part of the hydraulic press known as the container (*see* Fig. 1), the inlet being afterwards sealed. While the metal is in a semi-molten condition considerable pressure (50,000 lb. per sq. in. for small diameter pipes, down to 15,000 lb. per sq. in. for those of large diameter) is exerted on the ram and also on the lead in the container. The result is that lead is forced out of the container (the only outlet being the space between the die and core) and issues in the form of piping. By adjusting the applied pressure on the ram, and changing the dies and cores, pipes of all sizes and weights can be obtained. The ends of the smaller diameter pipes, on issuing from the press, are taken over rollers and wound on drums, forming coils (*see* Fig. 3, p. 651). These are afterwards weighed and stamped.

Lead pipes of 1 in. diameter and under are usually sold in 60-ft. coils and marked with the weight per 15-ft. length (London and the South), or per yard (in the North of England). Pipes 1¼ to 2 in. diameter are marketed in 12-ft. lengths or 36-ft. coils, and marked with the weight per 12-ft. length.

The larger sizes of pipe, on issuing from the press, are supported at the ends and lifted vertically, being subsequently cut into 10-ft. or 12-ft. lengths. The weight of these large sizes is marked per 10-ft. length, or described as equal to sheet lead of a certain weight per sq. ft. Obviously, although the diameter remains constant for a given size of pipe, the thickness of the pipe wall varies according to the purpose for which the pipe is required :

Diameter of pipe	Use	Weight per yard
1¼ in.	Overflow	7 lb.
1¼ in.	Water pressure 200 ft. head	21 lb.

TABLE I. Lead Supply and Distributing Pipes

	Internal Diameter in inches	External Diameter in inches	Weight per yd. in lb.
(*a*) For pressures not exceeding 110 ft. head of water. (48 lb. per sq. in.)	⅜	·74	4·5
	½	·87	6·0
	¾	1·16	9·0
	1	1·44	12·5
	1¼	1·71	16·0
	1½	1·99	20·0
	2	2·53	28·0
(*b*) For pressures exceeding 110 ft. head of water but not exceeding 250 ft. head of water. (108 lb. per sq. in.)	⅜	·76	5·0
	½	·92	7·0
	¾	1·23	11·0
	1	1·54	16·0
	1¼	1·83	21·0
	1½	2·10	27·0
	2	2·70	38·0
(*c*) For pressures exceeding 250 ft. head of water but not exceeding 400 ft. head of water. (173 lb. per sq. in.)	⅜	·81	6·0
	½	1·02	9·0
	¾	1·36	15·0
	1	1·68	21·0
	1¼	1·98	28·0
	1½	2·29	35·0
	2	2·85	48·0

TABLE II. Lead Flushing and Warning Pipes

Internal diameter in inches	External Diameter in inches	Weight in lb. per lineal yard
½	·71	3·0
¾	·99	5·0
1	1·26	7·0
1¼	1·52	9·0
1½	1·80	12·0
2	2·32	16·0

From B.S.S. 602

British Standard Sizes and Weights. The use of British Standard weights for lead pipe is rapidly increasing. They are now required by a number of important water authorities, including the Metropolitan Water Board. They are also referred to in the Model By-Laws issued by the Ministry of Health under the recent public health legislation. Tables I. to III. on this page are taken by permission from B.S.S. 602.

Table IV., page 740, gives common sizes and weights of lead pipe that are in general use for various purposes.

Sizes and weights of pipe other than those shown in Table IV. are made to special order. Pipes of 12-in. diameter and over are usually made by hand from sheet lead, which is bent over a suitable former and the seam " burnt " (*see* Lead-burning).

This method is also still occasionally used to make the smaller diameter pipes—where, for instance, short pieces are required.

Gas and Condensation Pipes. Lead pipes (generally referred to as composition pipes) are used extensively in gas fitting work, particularly where flexible connexions are required between iron supply pipes and various forms of gas consuming apparatus. Owing to the small amount of pressure these pipes have to withstand, they are made in practically the same weights as those used for flushing and warning pipes (*see* Table II.). Gas and condensation pipes can be obtained tinned or untinned on the outside. The smaller sizes are generally tinned.

Rectangular Pipe. Piping of rectangular section is produced by the extrusion process, as previously described, and the sizes usually manufactured are :

3½″ × 3½″ 4½″ × 4½″ 5″ × 4″ 3″ × 3″
4″ × 3″ 4″ × 4″ 6″ × 4″ 4″ × 2½″

in 12-ft. and 15-ft. lengths, and weighing 8 lb. per square foot of lead. Rectangular pipe is sometimes made by plumbers from sheet lead, by shaping over a suitable former and lead-burning the seam.

Cast Lead Pipe. Where piping is used for decorative purposes, cast lead is usually preferred, so as to conform to the finish of other ornamental architectural work, such as rainwater heads, gutters, etc.

It is usual to cast the lead flat on a sand table (*see* Cast Sheet Lead), and afterwards to trim to required width. The lead is then bent round either a circular or rectangular former—whichever section is required—and the seam burnt. The collars and ears

TABLE III. Lead Soil, Waste and Ventilating Pipes

Internal diameter in inches	External diameter in inches	Weight in lb. per lineal yard
1¼	1·46	7·0
1½	1·74	9·0
2	2·24	12·0
2½	2·73	14·4
3	3·23	17·1
3½	3·74	20·0
4	4·24	22·8
4½	4·77	29·1
5	5·34	41·0
6	6·40	57·0

From B.S.S. 602

TABLE IV.—Common Sizes and Weights of Lead Pipe

Internal diam. in.	External diam. in.	Weight per yd. in lb
1/8	·19	·25
3/16	·28	·5313
1/4	·32	·5
and in various sizes up to:		
1/4	·36	·75
1/4	·49	2·0
1/4	·57	3·0
1/4	·64	4·0
1/4	·76	6·0
5/16	·41	·5
and in various sizes up to:		
5/16	·56	2·25
3/8	·44	·625
and in various sizes up to:		
3/8	·63	3·0
3/8	·69	4·0
3/8	1·08	12·0
7/16	50	·75
and in various sizes up to:		
7/16	·60	2·0
1/2	·58	1·125
and in various sizes up to:		
1/2	·74	3·5
1/2	·77	4·0
1/2	·80	4·5
1/2	·83	5·0
1/2	·85	5·5
1/2	·97	8·0
and in various sizes up to:		
1/2	1·43	18·0
9/16	·84	4·5
5/8	·70	1·25
and in various sizes up to:		
5/8	·88	4·5
5/8	·91	5·0
5/8	·95	6·0
5/8	·99	7·0
5/8	1·04	8·0

Internal diam. in.	External diam. in.	Weight per yd. in lb.
5/8	1·08	9·0
and in various sizes up to:		
5/8	1·19	12·0
3/4	·89	2·75
and in various sizes up to:		
3/4	·95	4·0
3/4	1·04	6·0
3/4	1·08	7·0
3/4	1·11	8·0
3/4	1·19	10·0
3/4	1·26	12·0
3/4	1·51	20·0
7/8	1·05	4·0
and in various sizes up to:		
7/8	1·58	20·0
1	1·15	3·75
and in various sizes up to:		
1	1·22	6·0
1	1·3	8·0
1	1·33	9·0
1	1·37	10·0
1	1·4	11·0
1	1·43	12·0
1	1·48	14·0
and in various sizes up to:		
1	1·74	24·0
1 1/8	1·40	8·0
and in various sizes up to:		
1 1/8	1·60	15·0
1 1/4	1·44	6·0
1 1/4	1·49	8·0
1 1/4	1·55	10·0
1 1/4	1·58	11·0
1 1/4	1·60	12·0
1 1/4	1·63	13·0
1 1/4	1·66	14·0
1 1/4	1·68	15·0
1 1/2	1·72	8·0
1 1/2	1·77	10·0
1 1/2	1·79	11·0

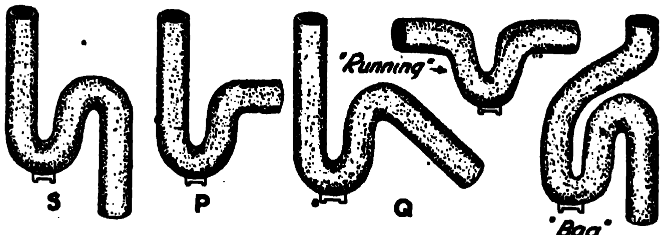
Internal diam. in.	External diam. in.	Weight per yd. in lb
1 1/2	1·86	14·0
1 1/2	1·91	16·0
1 1/2	1·95	18·0
1 1/2	2·02	21·0
and in various sizes up to:		
1 1/2	2·25	33·0
1 3/4	2·05	13·0
1 3/4	2·09	15·0
and in various sizes up to:		
1 3/4	2·37	30·0
2	2·18	9·0
and in various sizes up to:		
2	2·28	14·0
2	2·36	18·0
2	2·41	21·0
2	2·46	24·0
2	2·57	30·0
2 1/4	2·49	13·5
and in various sizes up to:		
2 1/4	2·92	40·0
2 1/2	2·68	11·0
and in various sizes up to:		
2 1/2	3·23	48·0
2 3/4	2·99	16·0
and in various sizes up to:		
2 3/4	3·44	50·0
3	3·15	11·0
3	3·24	18·0
3	3·48	36·0
3	3·59	45·0
and in various sizes up to:		
3	3·93	75·0
3 1/2	3·67	14·4
3 1/2	3·96	40·0
3 1/2	4·00	45·0
3 1/2	4·05	48·0
and in various sizes up to:		
3 1/2	4·22	64·0

Internal diam. in.	External diam. in.	Weight per yd. in lb.
4	4·17	16·2
4	4·19	18·0
4	4·25	24·0
4	4·28	27·0
4	4·3	30·0
4	4·49	48·0
and in various sizes up to:		
4	4·87	90·0
4 1/2	4·67	18·0
and in various sizes up to:		
4 1/2	5·24	84·0
5	5·19	22·5
and in various sizes up to:		
5	5·73	91·0
5 1/2	5·71	27·0
and in various sizes up to:		
5 1/2	6·24	100·0
6	6·19	27·0
and in various sizes up to:		
6	6·86	130·0
6 1/2	6·95	70·0
and in various sizes up to:		
6 1/2	7·10	95·0
7	7·5	84·0
and in various sizes up to:		
7	7·82	150·0
7 1/2	8·14	115·0
8	8·67	130·0
8 1/2	9·24	152·0
9	9·87	180·0
10	10·89	215·0
11	11·98	260·0
12	13·10	320·0

for this cast pipe are usually made separately, and are then "burnt" on to the length of prepared pipe.

Lead Pipe Alloys. By the addition of other metals in small proportions to lead, alloys are produced which give increased strength to pipes made of this metal. The two alloys used in the building trade are known as (1) Ternary Alloy; (2) Tellurium Lead. The characteristics of these metals are dealt with fully under the heading Lead.

Tin-Lined Lead Pipe. Pipes are supplied lined with tinned copper or block tin and are used where it is considered possible that the fluid to be carried may have a detrimental dissolving effect on the normal lead pipe.



PIPE: LEAD. Fig. 2. Five patterns of lead trap used in modern practice. (See also under heading Traps.)

most necessary that the thickness of the lead in the finished trap should be uniform, the tendency being for the lead on the outside of the bend to become very thin during the bending process.

Traps Made by Hydraulic Extrusion. The introduction of hydraulically extruded traps was a boon to the plumbing trade and led to the saving of time and expense, as compared with the old methods by means of which a more costly but distinctly inferior article was produced.

The machine for producing traps (Fig. 3) resembles the pipe press. The die is similar, but the mandrel is short and the plunger which forces the lead through the die is made in two halves. The lead is placed in a divided container, and if the pressure on the two rams is applied equally an ordinary straight length of pipe is produced.

By the operator causing one ram to become almost stationary while the other moves forward, the pipe at the side at which the pressure is least is forced round by the more rapidly moving lead on the other side. The alternative movement and variation of speed of the rams enables bends of any degree and radius to be obtained.

The traps shown in Fig. 2 can be obtained in all intermediate sizes from 1 in. to 4 in. dia., with or without cleaning screws and in various weights, that is, the thickness of the lead forming the trap is said to be equal to sheet lead of a certain weight in lb. per square foot. Taking a size at random from a catalogue it is found that 2-in. traps of the types illustrated above are supplied in weights ranging from 5 lb. to 12 lb.

In addition to those illustrated in Fig. 2 various other traps have been introduced, with the object of providing a self-contained means of preventing siphonage, thereby avoiding the need to provide an anti-siphonage, or ventilation pipe (*see* Anti-Siphon Pipe, where these traps are

C. TRAPS, BENDS, ETC.

The introduction of the pipe trap in plumbing work rendered obsolete many forms of trap which were insanitary and far from self-cleansing in their action. Among the various patterns originally designed, the following are still used in modern practice. They are: "S," "P," "Q," "Running" and "Bag" traps (*see* Fig. 2). *See further under* Traps.

As was the case on the introduction of lead piping, some time elapsed before manufacturing methods had developed to any great extent in the production of traps. Some of the first examples were hand-made from two pieces of sheet lead, joined by two soldered seams. For example, one piece of lead of sufficient width and length was bent to conform to the inside or throat of, say, a P trap. The edges were then worked to assume a semicircular section on a wooden or cast-iron block provided for the purpose. The other half was bent to the shape of the outside of the bend, being worked similarly on the block. After the two halves had been fitted and cleaned, the seam was usually soft-soldered. Traps made in this way did not give satisfactory service as the seams were not durable. Unless great care was taken when joining the two halves it was a common occurrence for the solder to find its way, in places, to the inside of the trap. These projections formed obstructions where suspended matter could collect, gradually to bring about a complete stoppage of the pipe.

Another method used in making traps by hand was to bend extruded lead pipe with the aid of bobbins, dummies, etc. (*see* Pipe Bending). This operation called for a high degree of skill, as it was

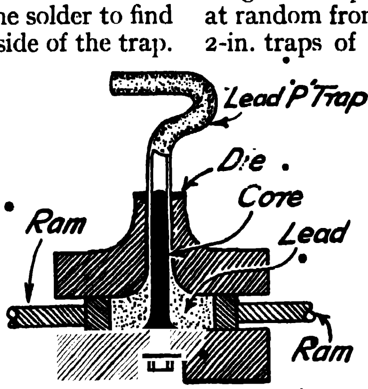
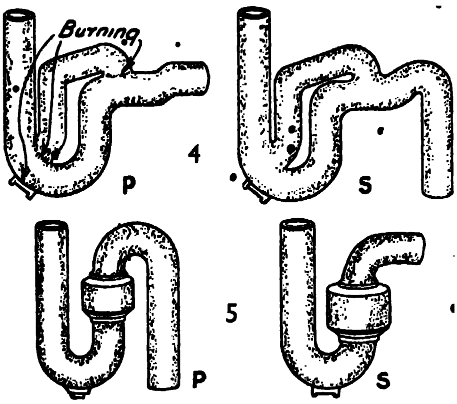


Fig. 3. Section of lead press for producing traps and bends, with lead in container and "P" trap extruded. See text.



PIPE: LEAD. Figs. 4 and 5. Patent traps in lead incorporating means of anti-siphonage; (two top) Greenwood's "Grevak" traps; (two bottom) resealing type traps (for further description, see text below).

discussed). The traps are produced by the hydraulic process, the additional pipes and chambers being subsequently "burnt" on in the required position. Figs. 4 and 5 illustrate two popular types of patent trap, these being obtainable with inlets and outlets arranged in various lengths and angles to order. The types shown in Fig. 4 are obtainable in sizes from 1 in. to 3 in. dia., and made in a variety of weights (*e.g.*, a 1½-in. P trap is made in 5, 6, 7, or 8 lb. weight). The resealing traps in Fig. 5 can also be obtained in various sizes, lengths, etc., from 1 in. to 2 in. dia.; and these sizes are made in lead of 6 or 7 lb. weight. *See also* Trap.

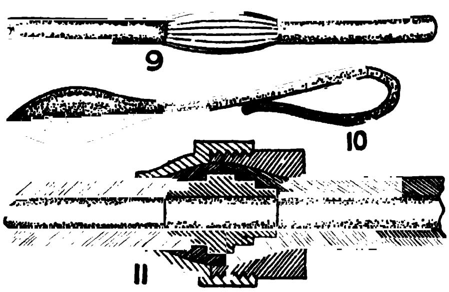
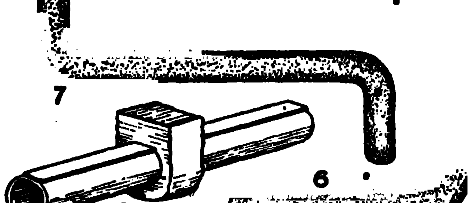


Fig. 9. Completed joint made with tin and lead alloy and smoothed with the plumbing iron of Fig. 10. Fig. 11. Tylor's patent "Grooved" joint for connecting two lead pipes of equal sizes without the use of solder.

Lead Bends. A large variety of ready-made bends is obtainable from lead merchants, the sizes ranging from 1¼ in. to 6 in. dia. (*see* Fig. 6). They are supplied in any required weight, length or angle.



Figs. 6 and 7. Ready-made bends; (6) single bend; (7) offset bend. Fig. 8. Pipe jointed in sand mould, method used by ancient craftsmen. (See text.)

In addition, offsets (Fig. 7) are stocked, made of 3½ and 4-in. dia. pipe in several projection lengths.

D. JOINTS AND JOINTING

For detailed information about the making of joints of all types to lead pipes, the reader should consult the first article of the Joints group, beginning in p. 618.

Jointing. With the introduction of lead piping many methods were tried with the object of developing a simple and efficient technique whereby lengths of this pipe could be joined. Many examples of the way the ancient craftsman made these joints are in existence, and it will be of interest to give a brief outline of the operation. After the pipes were made, the ends were trimmed evenly and were brought together; a sand mould was made of sufficient dimensions to allow for a generous amount of lead to surround the joints. (*See* Fig. 8.) A core of sand was packed into the pipes. Hot lead was then poured into the mould to melt the ends of the pipe, enabling the added metal to adhere. This formed a burnt joint and was successful where the pipes were of uniform thickness and the molten lead was of the correct temperature on pouring into the prepared mould.

The method which followed this crude process of burning is similar to present-day practice, and consists of applying to the joint a mixture of tin and lead as a jointing medium. This alloy, in addition to having a melting point considerably lower than that of lead, possesses the advantage that a fair period elapses before the molten metal solidifies, giving time in which roughly to shape the plastic metal into the desired form. After the metal had solidified, the joint was finished by lightly smoothing with a hot "plumbing iron" (Fig. 10); this tool was drawn lengthwise over the joint to give it a finished appearance and was supposed to prevent the joint from being porous.

The method now in use (wiping a soldered joint) is similar except that more skill is evident on the part of the crafts-

man; he is able to complete a joint before the metal has solidified, and normally requires no additional form of heat unless the joint is in a very awkward position.

Many forms of mechanical joint or coupling have been introduced from time to time, but none seems able to supersede the wiped joint; and although the last named is very difficult for anyone other than a skilled craftsman to make, the method is reliable and lasting. *See under* Joint.

Lead-Burning. Increasingly employed as an alternative method to the wiped joint in lead soil, waste and service work, for methods employed *see* Lead-Burning.

Special Joints. The "Staern" joint is illustrated in p. 628. It is applicable to lead piping of equal diameter or to tail-pieces, unions, or caps and linings for connecting to sanitary and water fittings.

Tyler's patent "Grooved" joint (Fig. 11) depends upon the compression of the lead pipe between a brass union and a grooved or stepped fitting in the bore.

Other manipulative joints such as the "Gripross" and the "Securex" solderless compression joints have been designed for economy in jointing lead to lead and lead to iron for water, gas and waste pipes. They are, in effect, compression joints.

PIPE AND PIPE FITTINGS: (2) BRASS AND COPPER TUBES

By A. L. McMullen, M.A., A.R.I.B.A., and E. Carr, Ph.D., B.Sc., M.I.P.

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Here details are given of the various kinds of tube and the fittings used with them. Fuller information on the practical aspect of joints and jointing is given in the next article of this Group. The sections are as follows: A, Heavy Gauge Tubes; B, Light Gauge Tubes; C, Brass Tubes.

One of the great advances in human development was the replacement of stone by metals. That began with the discovery of copper. Archaeologists dispute the dating, but it seems probable that copper was known in Asia some 6,500 years ago, and that it was brought to Egypt about 4,200 B.C. When the alloy with tin was discovered—between 3,000 and 2,000 B.C.—the Bronze Age of civilization opened.

Copper tubes for conveying domestic water services were certainly used by the ancient Egyptians. The first copper tube was formed from a piece of beaten sheet copper folded around a mandrel, and the seam covered with gypsum, as used in the temple of King Sa-hu-Re at Abusir about 2,750 B.C. Many of the baths used by the Romans had water piped to them from pipes of copper similarly formed. Earlier, copper and bronze were in limited use in the Early Minoan civilization about 3000 B.C. In the 1st Dynasty of Ur in ancient Mesopotamia, about 3,100 B.C., copper was fashioned in temple objects of excellent craftsmanship.

The manufacture of copper into seamless tubes involves three main processes: the first stage is the casting of a cylindrical billet in a cast-iron or water cooled copper mould; next the billet at red heat is converted into a long, hollow shell in an extrusion press or rotary piercing machine; the third stage consists of drawing down the shell while cold through hard metal dies by means of successive passes on a draw-bench until the desired diameter and wall thickness are obtained. Seamless drawn tubes with a diameter as large as 24 in. can thus be produced. Tubes of the sizes commonly used in building work are manufactured accurately with small tolerances. This accuracy is particularly necessary when the tubes are to be jointed with fittings manufactured to suit the particular diameter and thickness of tube.

A. HEAVY GAUGE COPPER TUBES

Although light gauge tubes suitable for jointing by means of compression, capillary or welded joints are now universally employed for domestic hot and cold water and heating services, heavy gauge tubes, sufficiently thick to take a screw thread, are sometimes used in heating work, particularly for steam services or for pipes in which the hydraulic pressure is high. The dimensions of these tubes are laid down in B.S. 61, Part 1, 1947 (*see* Tables IV and V, page 745).

Jointing of Heavy Gauge Tubes. Copper tubes to B.S. 61, Part 1, 1947, are jointed with cast copper alloy threaded fittings. *See* B.S. 99:22. The desired composition of these fittings is specified,

TABLE I—**British Standard Light Gauge Copper Tubes for Water and Gas** (*B.S.*659 : 1944)

Nominal Size	Standard Outside Diameter	Actual Bore	Thickness		Weight per Foot
In.	In.	In.	S.W.G.	In.	lb.
⅛	0·205	0·149	22	0·028	0·06
¼	0·346	0·274	20	0·036	0·135
⅜	0·471	0·399	20	0·036	0·19
½	0·596	0·516	19	0·040	0·27
¾	0·846	0·766	19	0·040	0·39
1	1·112	1·016	18	0·048	0·62
1¼	1·362	1·266	18	0·048	0·76
1½	1·612	1·516	18	0·048	0·91
2	2·128	2·016	17	0·056	1·40
2½	2·628	2·516	17	0·056	1·74
3	3·144	3·016	16	0·064	2·38
3½	3·660	3·516	15	0·072	3·12
4	4·184	4·024	14	0·080	3·97

Note.—Tolerances are: plus 0; minus 0·503 in. for ⅛ in. to 2 in. tubes and 0·006 for 2½ in. to 4 in. tubes.

TABLE II—**Light Gauge Copper Tubes for Sanitation Purposes** (*British Standard* 659 . 1944)

Nominal Size	Standard Outside Diameter	Actual Bore	Thickness		Weight per Foot
In.	In.	In.	S.W.G.	In.	lb.
1½	1·612	1·516	18	0·048	0·91
2	2·128	2·032	18	0·048	1·21
2½	2·628	2·532	18	0·048	1·50
3	3·144	3·032	17	0·056	2·09
3½	3·660	3·548	17	0·056	2·44
4	4·184	4·056	16	0·064	3·19

Note.—Tolerances are: plus 0 and minus 0·003 in. for 1½ in. and 2 in. and 0·006 in. for 2½ in. to 4 in. tubes.

and the threads for the high pressure tubes are identical with those for iron and steel tubes. For jointing methods *see* Pipes: (3).

B. LIGHT GAUGE COPPER TUBES

The present widespread use of light gauge copper tubes for hot and cold water services, heating and sanitation, etc., has come about as a result of the development of jointing methods, which do not require the cutting of a thread on the pipe wall. For all normal building conditions, the tube walls, whilst thinner than those laid down in B.S. 61, are more than sufficiently strong to resist damage, or corrosion. For instance, the bursting pressure of a ¾-in. copper tube to B.S. 659: 1944 is approximately 4,000 lb. per sq. in. These lighter tubes have formed the subject of a British Standard, No. 659:1944. Table 1 gives the gauges of those used for water and gas services, and Table 2 those for use for sanitation services. The specification requires the tube to be of de-oxidized arsenical copper and in half hard temper. The fact that they are de-oxidized makes them suitable for jointing by copper or bronze welding.

Pipes for Underground Use. Until recently, copper was not used to any large extent for underground services, but following upon extensive research and field trials, it has been proved conclusively that copper offers a greater resistance to soil corrosion, by almost all types of soil, than does any other pipe metal. Pipes of any metal, passing through earth which is especially corrosive, should be protected. Either lay the pipe in a wooden trough and fill with bitumen, or surround it with sand or chalk, which will have the effect of neutralising the acidity in the soil.

A British Standard No. 1386:1947, shown in Table III, gives the sizes of copper tubes for use on underground mains. They are adequate to resist all normal shocks or crushing loads, and cases of failure of buried copper pipes from flattening or crushing are virtually unknown.

TABLE III—**British Standard Sizes of Copper Tubes to be Buried Underground** (*B.S. No.* 1386 : 1947)

Nominal Size	Standard Outside Diameter	Actual Bore	Thickness		Weight per Foot
In.	In.	In.	S.W.G.	In.	lb.
½	0·596	0·500	18	0·048	0·319
¾	0·846	0·734	17	0·056	0·536
1	1·112	0·984	16	0·064	0·812
1¼	1·362	1·234	16	0·064	1·006
1½	1·612	1·468	15	0·072	1·342
2	2·128	1·968	14	0·080	1·983
2½	2·628	2·444	13	0·092	2·824
3	3·144	2·936	12	0·104	3·826
3½	3·660	3·428	11	0·116	4·975
4	4·184	3·928	10	0·128	6·282

Note.—Tolerances on mean thickness are plus or minus: 0·004 in. for ½ in. to 1½ in. tubes; 0·006 in. for 2 in. to 4 in. tubes.

The outside diameters of copper tubes to this Specification are the same for size as those laid down in B.S. 659:1944. This ensures that the same fittings may be used with either pipe.

Copper tubes to B.S. 1386:1947 can be obtained in half hard temper in random lengths up to 20 ft., or in dead soft temper in coils up to 60 ft. The advantage of using the coiled long length tube is, of course, that it cuts down the number of joints for a given length of pipe.

Jointing Fittings for Light Gauge Copper Tubes. The two most commonly used methods for jointing light gauge copper tubes, especially for the smaller sizes of tube, that is up to 2½ in. diameter, are by means of compression and capillary fittings. These are covered by B.S. 864:1945.

Compression Fittings. Joints made with compression fittings may be defined as mechanical joints made without resort to threading the pipes, or to soldering, welding or brazing; they are made water- or gas-tight by the tightening of a nut or nuts

TABLES IV AND V—Copper Tubes for Pressures up to and Including 300 lb. per sq. in. (*B.S.* 61 : 1947)

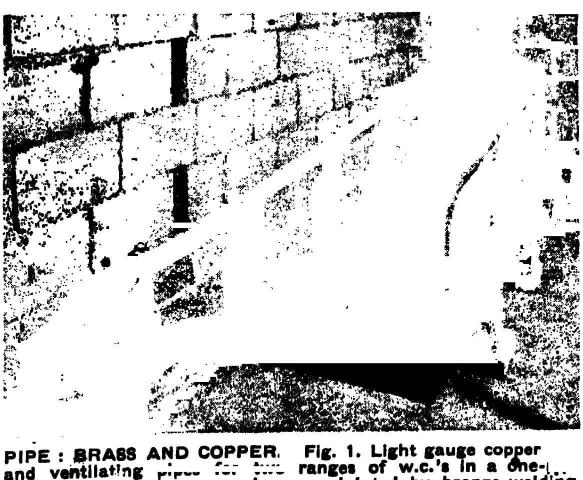
TABLE IV—Pressures up to 175 lb. per sq. in.						TABLE V—Pressures over 175 lb. and up to 300 lb. per sq. in.					
Nom. Size (Bore) In.	Outside diameter		Thickness		Mean Weight per linear ft.	Nom. Size (Bore) In.	Outside diameter		Thickness		Mean Weight per linear ft.
	Max. In.	Min. In.	S.W.G.	In.	lb.		Max. In.	Min. In.	S.W.G.	In.	lb.
½	0·653	0·647	13	0·092	0·621	½	0·840	0·834	11	0·116	1·012
¾	0·906	0·898	13	0·092	0·902	¾	1·058	1·050	10	0·128	1·434
1	1·172	1·164	12	0·104	1·339	1	1·328	1·320	9	0·144	2·056
1¼	1·422	1·414	12	0·104	1·654	1¼	1·669	1·661	8	0·160	2·914
1½	1·672	1·664	12	0·104	1·968	1½	1·901	1·893	7	0·176	3·665
2	2·199	2·189	10	0·128	3·200	2	2·368	2·358	6	0·192	5·043
2½	2·699	2·689	9	0·144	4·443	2½	2·981	2·971	5	0·212	7·092
3	3·223	3·213	9	0·144	5·356	3	3·481	3·471	4	0·232	9·107
3½	3·750	3·738	8	0·160	6·939	3½	3·973	3·961	3	0·252	11·328
4	4·274	4·262	7	0·176	8·714	4	4·473	4·461	2	0·276	13·996

(*see* Compression Joint). Broadly, compression fittings are of two main types :

(*a*) Those which require the ends of the tube to be enlarged, cupped, flared or flanged with special tools, and in which the joint is made by compressing the flared or flanged ends against the turned faces of the body of the fitting or of a loose thimble.

(*b*) Fittings requiring no preparation of the tube ends other than cutting them off square with a hack-saw. In these cases the fluid-tight joint is made by a ring or sleeve, or part of the fitting, which is caused to grip the outside of the tube wall.

Compression fittings of both types are available for tubes up to 6 in. in diameter. For tubes over 2 in., however, fittings become increasingly heavy, bulky and expensive and accordingly jointing by bronze-welding is now often employed for the larger sizes of pipes such as soil and ventilating pipes.



PIPE : BRASS AND COPPER. Fig. 1. Light gauge copper and ventilating pipes for two ranges of w.c.'s in a one-[illegible] installation. The copper pipes are jointed by bronze-welding.

Gordon Jeeves, F.R.I.B.A., Architect: J. Stinton Jones & Partners, Consulting Engineers (Courtesy Copper Development Assn.)

Soft-solder Capillary Fittings. Capillary fittings consist of a copper or brass jointing piece with sockets into which the tube ends fit closely. The making of the joints is described in pages 753–754.

Capillary fittings are small in bulk and neat in appearance, and although obtainable in sizes up to 4 in. in Great Britain, are used generally for the smaller sizes of tubes. They are readily obtainable for all standard tube diameters up to 2½ in. and for the usual gauges. They are used extensively for hot and cold water supply pipes, heating pipes, gas pipes and the smaller sizes of sanitation pipes. In America they have been developed in the larger sizes for soil pipes.

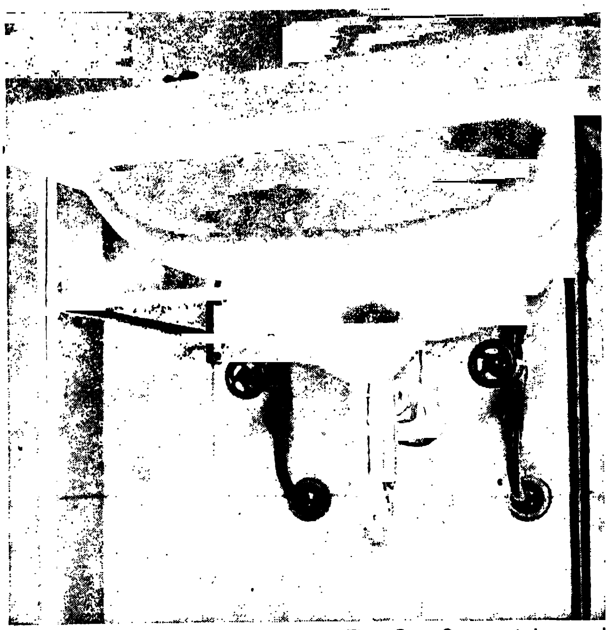
The chief difference in the various types of fittings on the market lies in the way in which the solder is fed into the capillary space which is either (*a*) from the mouth of the sockets ; (*b*) through touch holes in the sockets ; or (*c*) from pre-formed rings of solder already within the sockets.

Typical compositions of soft solders used with capillary fittings are 50 per cent. tin, 50 per cent. lead (melting range 185° C. to 215° C.) ; 39 per cent. tin, 60 per cent. lead, 1 per cent. antimony (melting range 185° C. to 230° C.) ; 95 per cent. tin, 5 per cent. antimony (melting range 235° C. to 240° C.).

The process of jointing by soft-solder capillary fittings is fully described and illustrated in the next article of this Group. *See* pages 753–754.

Capillary fittings can, of course, be brazed to the copper pipes with a hard solder if exceptional strength and reliability are required. If the fittings are of brass, a silver solder rather than a brass brazing spelter should be used as it obviates the risk of damage to the fitting by overheating.

Weldable Fittings. Mention should be made of the cast copper fittings sometimes employed when bronze-welding is used for the jointing of copper pipes. These fittings consist of a cast copper sleeve having sockets with shoulders against which the tube ends abut, as in the soft solder capillary fittings. At the mouth of each socket is an annular recess in which the filler metal is deposited and built up to form a collar.



PIPE: BRASS AND COPPER. Fig. 3. Copper tubes and fittings to hotel lavatory basin. Note stop-valves on hot and cold supplies. Compression joints are used.
Copper Development Association.

The fittings can be obtained in the larger sizes for soil pipes, and simplify the preparation of the joints, but require two or three welds in the place of one. For branch joints in copper soil pipes the labour of working out a socket from the main pipe is saved. The fittings for branch joints are properly swept.

Jointing Methods. For jointing methods *see* the next article in the present Group, beginning in page 747.

See also under Welding: (2) Bronze-Welding.

Fig. 4. Soil and vent pipes in light gauge copper tube.
Copper Development Association.

C. BRASS TUBES

Brass tubes are not often used in Great Britain for "plumbing" work. They are sometimes employed for making the traps for lavatory basins and baths, and also for hot towel rails. In America, on the other hand, a large amount of brass tube is used for water services.

The composition of the brass for this particular purpose is usually 85 per cent. copper, 15 per cent. zinc. This alloy is said to be superior to copper in its resistance to corrosion by salt water and is used, for instance, for the pipes in salt water baths. In America brass tubes are often of heavy gauge and are jointed with tapped fittings similar to those used for heavy gauge copper tubes in Great Britain; but they may, of course, be jointed by means of compression or capillary fittings in the same way as copper tubes.

PIPE AND PIPE FITTINGS: (3) JOINTING OF BRASS AND COPPER TUBES

By A. C. Martin, M.R.San.I., R.P.

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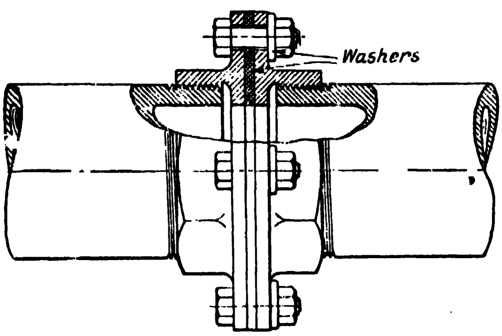
This article deals with the jointing of all types, including heavy gauge and light gauge tube. The Sections are: A, Screwed and Flanged Joints; B, Wiped Joints; C, Brazed and Silver-soldered Joints; D, Welded and Bronze-welded; E, Capillary Soft-soldered Joints; F, Compression Joints; G, Special Joints for Sanitary Work. Reference should be made to the article on One-pipe System for details of jointing methods used in that connexion.

The method of jointing copper tubes has in the past few years undergone a complete revolution. This is not because the means employed in the past were unsound, but is due to the fact that with new means of jointing (*i.e.* other than the screw and threaded socket joint) lighter



PIPE : JOINTING BRASS AND COPPER. Fig. 1. Detail of flange joint for thick-walled copper tubes, showing bolts outside and threads inside.

gauge tubes could be used. Thus the new methods of jointing made it possible to employ thin gauge tubes the strength of which was still more than enough to withstand ordinary hydraulic and other stresses to which they would be subject when employed for the conveyance of cold and hot water in buildings.

A. SCREWED AND FLANGED JOINTS

The original method entailed having a tube or pipe the walls of which had sufficient substance to allow a thread to be cut in the ends and still leave a margin of substance below the thread to withstand stresses set up by the process of fixing and by natural effects of expansion and contraction due to changes of temperature. This requirement, with the ordinary Whitworth or gas thread, involved the use of a tube with walls of substance at least equal to that of the mild steel or wrought iron barrel employed in building work. It made the adoption of copper tubes very expensive and limited the use of the metal to high-class work and to cases where it was imperative to use copper for reasons of its resistance to corrosion and erosion.

Concurrently with the wider use of thin-walled copper tubes many other means of jointing have been evolved, avoiding the use of screwed joints. Brazed and flanged joints have, of course, been used, the flanges being drawn up on to a washer with bolts; but while suitable for some classes of work in engineering, these joints were cumbersome and difficult to house in ordinary building work.

Joints for Thick-walled Copper Tube. Fig. 1 shows an ordinary flanged joint. The flanges are of gunmetal in high-class work, to avoid the association of entirely dissimilar metals, which might lead to corrosion.

Joints for Medium-thick-walled Tubes. The method of joining these is illustrated in Fig. 2. The thread is much finer than the ordinary standard gas thread. As the walls are relatively thin, and it would not be practicable to form a watertight or steamtight joint by screwing up with wrenches or spanners, the threaded ends of the tube and the threaded socket ends are tinned. The union shown is of high-quality brass or of gunmetal.

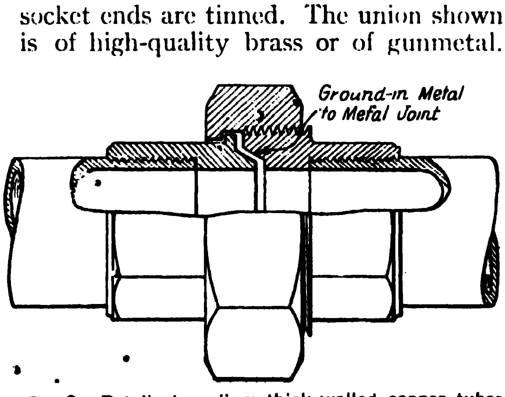


Fig. 2. Detail of medium-thick-walled copper tubes with union joint of high-quality brass or gunmetal.

The half of each union is screwed on to the ends of the tube to be jointed, making sure first to slip the fly-nut on the tube. The tinning should be clean, and a flux of non-corrosive nature must be smeared over the surfaces. The flame of a blowlamp is then played on the end until the tinning solder is melted. A little stick solder is added to flood up the top edge. The two halves of the union, with attached pipes, are then assembled and the fly-nut tightened up with a spanner until the meeting faces of the "ground-in" union form a watertight joint.

Bent unions and T pieces are, of course, obtainable, provided with the unions on the ends. When screwing up, another spanner should be placed on the facets of the female end and held, to avoid rupture of the attached tube by twisting when tightening up.

Flange Joint for Light Gauge Tube. Thin-walled or light gauge tubes have been used for certain classes of work where the somewhat cumbersome flange joint was not objected to. Fig. 3 shows this form of joint. The flanges are of good quality brass, and the tube end is flared over on to the meeting faces with a wooden mallet, finishing off with a smooth steel-faced hammer. The back edge of the flange is brazed on to tube. A washer is used between the meeting faces.

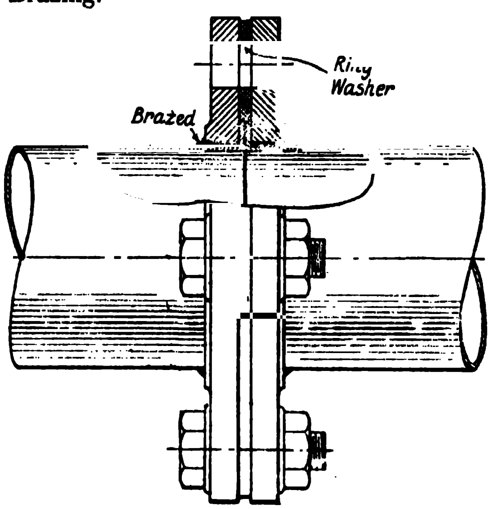
B. WIPED JOINTS

Ordinary coarse solder joints have been found unsatisfactory for ordinary building work, for both hot and cold services. The joints break down and become leaky after a time. Such joints, however, are used on tinned copper tubes of large diameter for conveyance of beer in breweries. The chief advantage is that the tinned lining is not destroyed in forming the joint, and so keeps the beer out of contact with the copper or other material which might have a deleterious effect on it.

C. BRAZED AND HARD-SOLDERED JOINTS

Brazing of copper and brass pipes is not general in building work, but it may be used where greater strength is required than would be given by fine-solder sweating. If brazing to brass, a brazing solder, (or spelter as it is usually termed) must be obtained having a lower melting point than that of the brass. The work must be cleaned and the parts to be brazed firmly fixed in position. The solder is in granulated or flake form mixed with borax, the latter acting as the flux. The work must be brought up to a low-red heat in a forge or by means of a powerful blowpipe. The solder and flux are then applied by a small iron spoon. The spoon can be formed by hammering the end of a stout piece of wire with the ball pane of a large hammer. If the solder refuses to unite with the surfaces it should be stroked round with the edge of the spoon and more flux added.

For more detailed information on brazing in general *see* the article on Brazing.



PIPE: JOINTING BRASS AND COPPER. Fig. 3. Detail of flange joint in thin-walled copper tube, the flange being of good quality brass or mild steel.

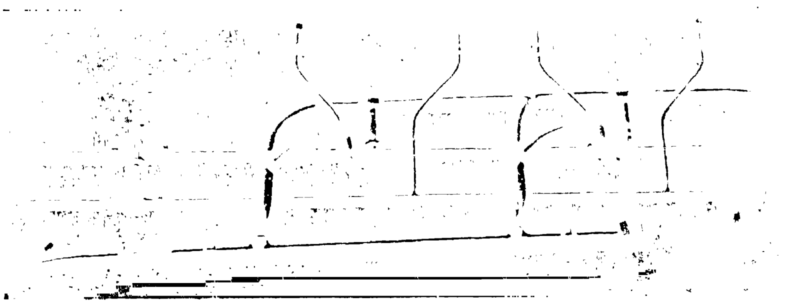
Silver-Soldered Joints. Both brazed and silver-soldered joints are classified as hard soldering as distinct from soft soldering, in which the solders are generally alloys of lead and tin. Hard solders consist of a mixture of copper and zinc in varying proportions, a 50–50 solder producing a fairly fluid and easily melted alloy. When it is required to obtain a lower melting temperature of the solder, silver is added.

Silver solder is more fluid and melts more easily than brazing spelter, so that it is very suitable for joining brass fittings and copper tubes where something stronger than soft soldering is required.

The solder is generally supplied in sheet form and is cut with shears into strips for application to the joint. Borax is used as the flux, and it is an advantage to

work it up to a paste by grinding it with water. A dull red heat is sufficient to form the joint. A powerful blowlamp, a brazier's gas-blowpipe or a welding blowpipe can be used for the work. The last-named is very manageable and convenient to use, both in the workshop and on the job. Recently silver solders of proprietary makes have been placed on the market which are very convenient to employ. Fluxes in paste form can also be obtained.

Fig. 4 illustrates an all-copper job as suitable for ranges of washbowls, sinks, etc. The tubes are in light gauge copper. For the silver-soldered joints the tubes are opened up and worked in the same way that lead pipes are opened up. The copper being a comparatively hard metal, however, it is necessary and expedient to work it at red heat. An assistant manipulates a blowpipe flame to localize the heat on the desired points, while the copper is worked up by the plumber. Care must be taken to make a close fit, so as to economize solder and ensure a strong job. If prepared properly the solder runs into the quirks in a similar way that soft solder runs in the capillary form of joint to be described later.



PIPE: JOINTING BRASS & COPPER. Fig. 4. Model of all-copper piping suitable for range of washbowls, sinks, etc., including vent, wastes, hot and cold supplies: pipes in light-gauge copper; joints silver-soldered.
Executed by students at Northern Polytechnic, London, N.7.

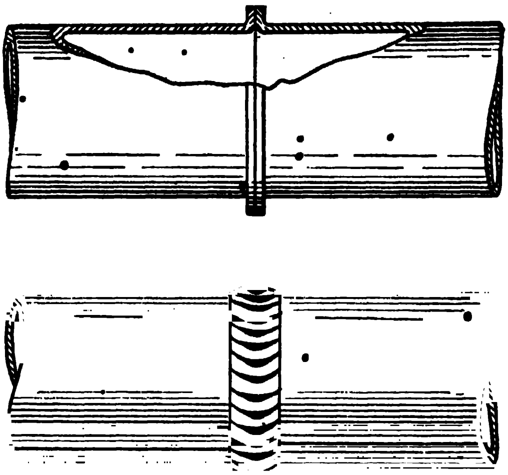
The silver-soldered joints may be picked out in the illustration by the neat, close and almost streamlined appearance. Though the solder is expensive (that used on the job illustrated cost 16s. ?d. per lb.), the cost worked out at less than 1½d. per joint average, owing to the small amount necessary. Where it was anticipated that such work might have to be taken down for repairs or cleaning out, joints of compression type were inserted. These may be seen on the traps and stop-valves. As set out, the work can be done on the bench and assembled in situ by means of the compression joints, several forms of which are described in a later page.

D. WELDED AND BRONZE-WELDED JOINTS

The subject of welding in general is discussed in a separate article under its own heading, but the special application to pipe joints is described here as a matter of convenience.

Welded joints are possible in copper, but special precautions are needed owing to the difficulty of ensuring sound work in every case with this somewhat "tricky" metal. Copper when fused to liquid very readily absorbs oxygen from the air or the gases of the welding blowpipe. This absorption leaves the welded metal weaker than the parent metal. Copper is also fragile at critical temperature, so that in cooling down the contraction effects may cause hair-like fissures to occur in the vicinity of the weld, or in the joint itself. In order to neutralize the effects of gas absorption, tube may be obtained of the quality known as de-oxidized copper. Special filler rods also of de-oxidized copper should be used for feeding the joint. Some makers of filler rod include traces of phosphorus in the rod to absorb oxygen, but the manufacture is a very delicate process, and excess of phosphorus will cause a weak joint.

Welds are executed with the oxy-acetylene flame, and special care should be taken to obtain a neutral flame of soft and non-rigid character, using the lowest possible oxygen pressure on the oxygen cylinder gauge. The luminous cone of the flame should never be pressed into the liquid bath of molten metal, but should hover above, about ⅛ in. away. Owing to rapid conduction rate of copper the metal should be evenly pre-heated with the flame of the blowpipe all round the joint and in its vicinity, before actual welding is begun. Pieces of asbestos sheet suitably placed will reduce conduction.



PIPE : JOINTING BRASS & COPPER. Fig. 5. Butt weld in light gauge copper tube : (top) detail of preparation of tubes, showing edges flared and flanged back (see text for further description) ; (bottom) finished weld.

Fig 5 indicates a method employed for butt joints in light gauge tube. The two edges are flared and flanged back to project about $\frac{1}{16}$ in. beyond the wall of the pipe. After cleaning, these edges are then fused down to the parent metal, thus forming a reinforced butt joint. A suitable flux should be used sparingly to avoid blow holes. A slight " cess " will occur at the finishing point of the weld (which, of course, worked in a rotary manner, is the commencing point). A piece of de-oxidized filler rod should be at hand to fill this cess; otherwise no filler rod is needed for this type of joint. Branch joints can be executed in the same way if, in opening the branch, care is taken to leave and work sufficient metal to form a socket above the crown of the pipe (*see* Fig. 6).

For running joints in an upright pipe welded in situ, it is recommended that the bottom edge of the top pipe only should be flanged back. There is less likelihood of holes occuring under the flame by that method. This is indicated in Fig. 7.

Copper welding has thus been described briefly, but it can be taken that for work in situ on a building, the process presents difficulties which are not easily overcome ; and it should be understood that for satisfactory work bronze-welding offers a safer and more reliable method, at any rate for the man who only occasionally uses the welding blowpipe. Bronze-welding is easier than welding copper with copper and is more reliable, particularly for forming joints in awkward positions.

Bronze-Welding. This process consists of uniting copper tubes by means of the oxy-acetylene welding blowpipe, using a filler rod of high quality brass. One such rod is that known as " Sif-bronze," and another (slightly more fluid and easier to work) is " Alda-bronze."

The process is really one of brazing, but with this difference, that a welding blowpipe is used and the bronze rod is fused in spot by spot round the joint. The finished joint comes out a golden colour in a series of waves similar to, but more defined than, the waves produced in ordinary welding and lead-burning. An advantage over ordinary brazing is that the joint can be reinforced by added filler rod.

The preparation of the work is important. Straight or running joints are prepared by opening one end to form a lip or cup to hold the filler rod fusions

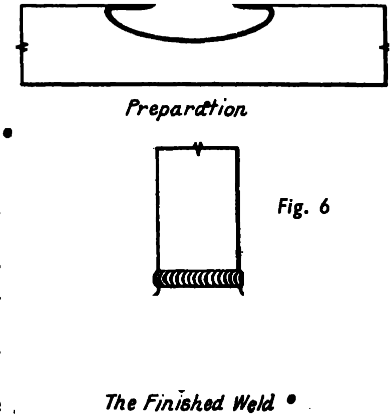


Fig. 6

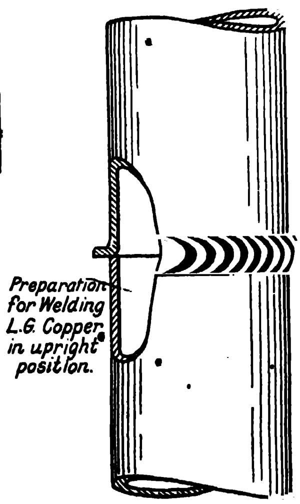
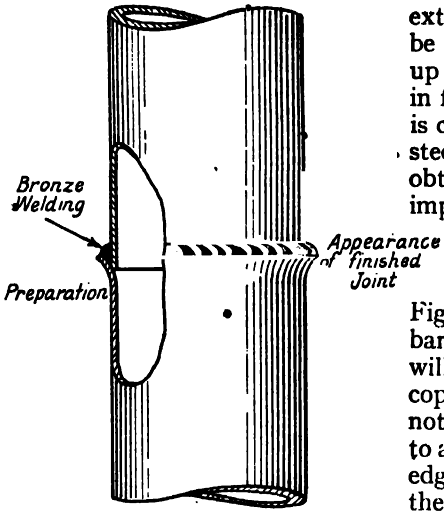


Fig. 7

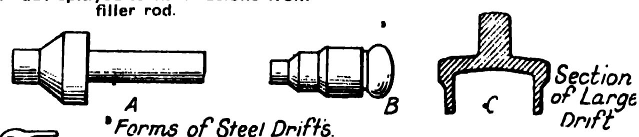
Fig. 6. Branch joint in light gauge copper tube, made with butt weld in similar way to that of Fig. 5. Fig. 7. Butt weld in upright light gauge copper tube, welded in situ. In this case the top pipe only is flanged back.

(*see* Fig. 8). Special steel tools may be obtained for opening the tube end. In Fig. 10 at A is shown a mandrel or drift which, when driven in, forms a lip concentric to the pipe. B shows a tool which is suitable to open tubes of two diameters (say ½ in. and ¾ in.), and another for 1 in. and 1¼ in. tube. For the bigger diameters the drifts are more suitable when made to open one size only. To reduce the weight further and thus to get a more effective driving force from the hammer blows, the barrel should be hollow. This tool is shown in C, Fig. 10.



PIPE : JOINTING BRASS & COPPER. Fig. 8. Joint in copper tube, bronze-welded with oxy-acetylene blowpipe ; lower tube splayed to take fusions from filler rod.

The cupping should not be carried to an excessive extent, as the cavity will be more difficult to fill up and will be expensive in filler rod. About ⅛ in. is correct. Where proper steel drifts cannot be obtained, one can be improvised by means of short pieces of steam barrel and sockets. This is indicated in Fig. 10, D. A piece of iron barrel is selected which will slip easily into the copper tube, or if it will not go in it is filed down to a suitable slip-fit. One edge of the socket is then filed to an angle of 45 degrees and screwed on to the short end of the



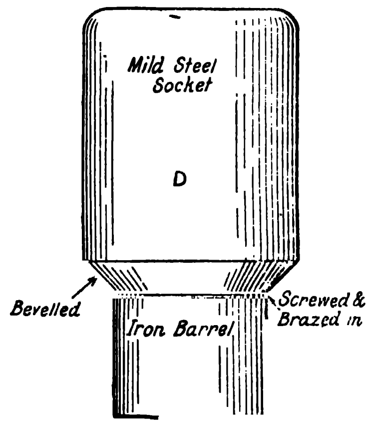


Fig. 10. Drifts for opening tube end ready for bronze-welding : A, B, and C, special steel drifts (for method of use, see text) ; D, improvised drift made of piece of iron barrel and steel socket (to open socket end of copper tube for bronze-welding).

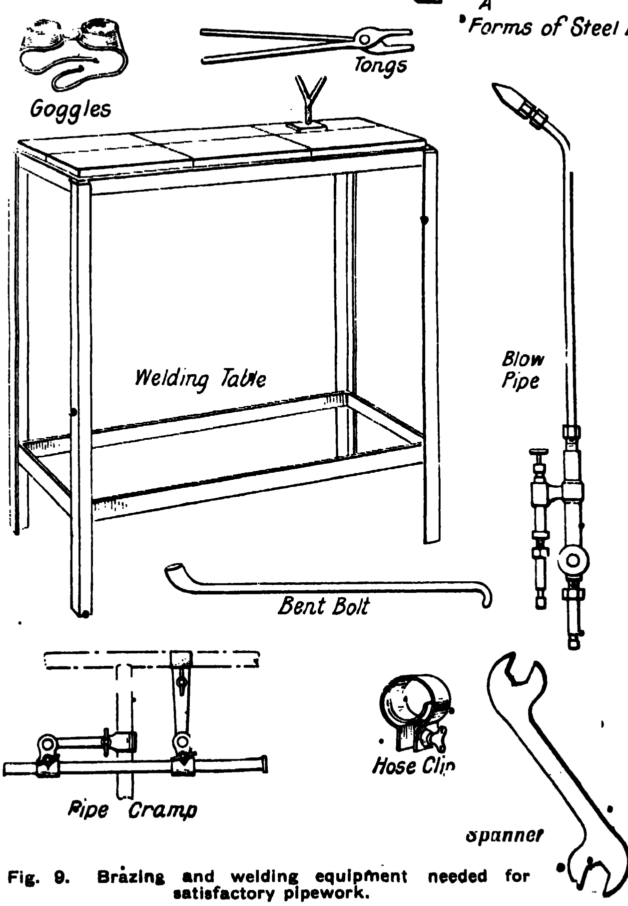


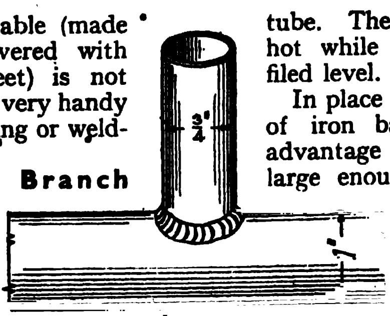
Fig. 9. Brazing and welding equipment needed for satisfactory pipework.

iron barrel. By brazing the pipe to the socket with the blowpipe flame, the worker will avoid the risk of the pipe becoming unscrewed and falling down the copper tube.

Fig. 9 shows a number of additional tools required for satisfactory work of this

character. The welding table (made from angle iron and covered with firebrick or asbestos sheet) is not essential on the job, but is very handy where an amount of brazing or welding has to be done.

Bronze-Welding Branch Joints. The main tube is opened by boring a small hole and then enlarged with a bent bolt and hammer, and worked up to form a socket above the crown of the pipe. If the edge is kept red hot with a welding flame, opening is easier and there is less risk of splitting the edge. This socket edge is cupped in the same way as the straight pipe and the joint made in a similar manner. For tubes of very small diameter (as for instance, entering a ½ in. branch tube to a ¾ in. main) the smaller tube can be fitted butt to the hole in the main and a bronze-welding made around the junction. Fig. 11 shows the finished joint.



PIPE : JOINTING BRASS & COPPER. Fig. 11. Bronze-weld : branch joint of small diameter copper pipe to one of larger diameter.

Fig. 12 illustrates the position and appearance of a bronze weld in the larger diameters. For branches larger than 1 in., two small holes should be bored, as in Fig. 13. These holes are drilled ⅜ in. to ½ in. from the edge of proposed hole to receive the branch, and the tube is slit between two holes. The area to be opened is then brought up to red heat with the localized flame of blowpipe, and the slit quickly opened by inserting the point of a knife in one hole and striking along and upwards with a medium weight hammer. The hole is next opened further with a bent bolt and hammer until the necessary socket is formed above and clear of the bore of the tube. The copper is kept red-hot while opening, and the edge filed level.

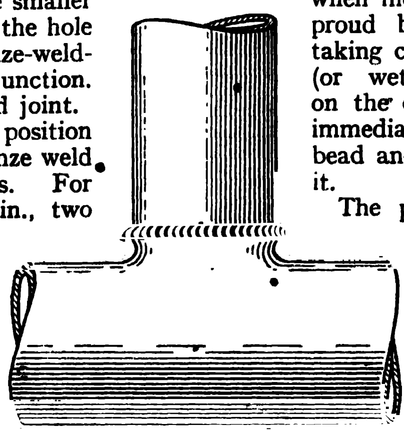


Fig. 12. Appearance of bronze-weld on branch joint to larger diameter water service pipe. *Compare* weld of Fig. 11 on smaller pipe.

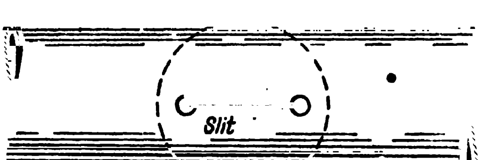


Fig. 13. Preparation of hole in main pipe to take square branch joint (see text above).

In place of the bent bolt a piece of iron barrel can be used with advantage as soon as the hole is large enough to enter it. Ragged edges of the hole should be avoided, as any jags will lead to tearing. The edge is cupped over to form a receptacle or shelf for the filler rod, the finished joint being as in Fig. 12.

A flux is necessary with bronze welding. The parent metal is brought up to red heat, *not* melted. The cone of the flame should be played into the bottom of the cup and the filler rod applied until the surface becomes "wetted" with the bronze, when more is applied to form a proud bead on the face, but taking care that it is well fused (or wetted, as it is termed) on the edges. This is repeated immediately next to the finished bead and practically overlapping it.

The process is repeated until the circumference of the joint is completed. A secret of success is to play the flame right into the quirk of the preceding bead and in the lower depths of the socket. If the flame and rod are applied only $\frac{1}{16}$ in. away oxide is formed and trapped between, causing a "cess" and checking the progressive flow.

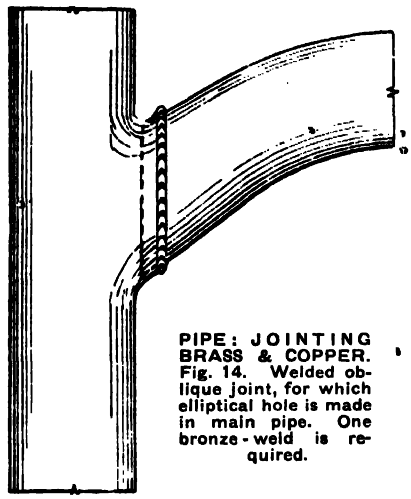
A flame containing a slight (but only slight) excess of oxygen is an advantage—particularly so when bronze-welding copper tube to brass fittings is being undertaken.

Joints can be made in any position, provided reasonable access is possible, but it is an advantage to make as many as possible on the bench. Branch joints in sanitary work (waste, soil, and vent pipes) must be oblique and in the direction of flow. The preparation is the same except that the hole to receive the oblique

branch will be elliptical instead of circular. *See* Fig. 14 for type of joint.

Weldable Fittings. Special "weldable" fittings in copper have been placed on the market. They are made specially for bronze-welding and have a shoulder to receive the plain end of the tube; the edge of the fitting has an annular space to receive the filler rod to form the joint. Fig. 15 illustrates this fitting, the one shown by B being an oblique T or junction piece as required in sanitary work. The fittings with cost of joints are rather expensive but the cost is somewhat offset by reduction in labour of preparation. It will be noted, however, that three bronze-weldings have to be made as against one in the joint illustrated in Fig. 14. Fittings may be obtained for hot and cold water service, as well as for sanitary work.

(*See further under* Welding.)



PIPE: JOINTING BRASS & COPPER. Fig. 14. Welded oblique joint, for which elliptical hole is made in main pipe. One bronze-weld is required.

E. CAPILLARY SOFT-SOLDERED JOINTS

Soft-solder sweated joints have long been employed for joining copper tubes in certain classes of work, but it was formerly considered that such joints should be made upright, with the mouth of the joint uppermost so that the solder could seep downwards by gravity. Experiment has shown, however, that if a definite space of capillary dimensions is established between the wall of the tube and that of the fitting, solder will fill up the cavity by capillary attraction of the fluid metal, irrespective of the position of the joint. Joints can be made upside-down or in a horizontal position as easily and successfully as in the conventional upright position.

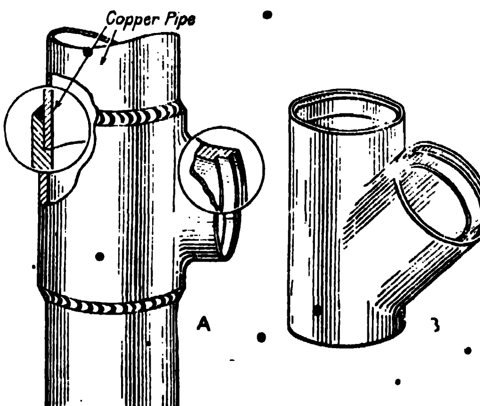


Fig. 15. Copper fittings for branch joints, with shoulders for plain ends of tubes. (A) Square T for water service: circles enclose enlarged sections—left, of joint; right, of socket ready for joint. (B) Oblique T. Three welds are required as compared with one for Fig. 14.

Essential Precautions in Preparing Joints. To ensure success the following points should be observed: The ends to be united must be perfectly clean, as also the inside of the sockets of the fittings. The maker's instructions should be carried out precisely. With tubes and fittings made to the appropriate British Standard, there is no need to fear that the tube and fittings will be other than the correct size, but attempts should not be made to fit heavier gauged tubes to the fittings, as hand filing is not accurate enough to ensure proper filling by capillary attraction. Failures in capillary joints in the past have been known to be due to attempts to file down the tube to enter fittings of a lighter gauge.

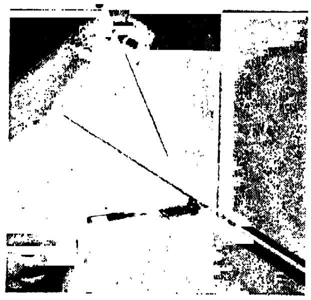
The inside of socket and ends of tube should be cleaned with steel wool or fine glasspaper, not with emery cloth. Dust from emery cloth might check the proper flow of the solder.

Solders and Flux. A flux of non-corrosive properties should be used. Makers of fittings usually market a suitable flux and solder. The solder used for general work is that known as 50-50, containing equal parts of tin and pure lead. For extra-strong work a solder composed of 95 parts tin and 5 parts antimony is recommended. *See also* Pipe: (2).

Fittings. There are several makes of fitting on the market. Some have to be fed with solder on the edge of the joint, so that it seeps in; another make has touch-holes about halfway down socket. (There are three touch-holes on each socket, so that one is always easily accessible.) When the joint is at the right temperature the solder stick is applied to the hole: the solder seeps in and the joint may be

considered sound when solder appears all round the edge of the fitting. A third type has an annular space halfway down the socket which is already filled with solder, so that it is unnecessary to apply stick solder.

Making a Capillary Joint. The general method is as follows. First clean all tube ends and inside of sockets. Immediately smear with flux, making sure to cover all surface within zone of joint. Assemble the work. Now apply the flame of a blowlamp on the outside of the joint; as soon as the flux shows signs of vaporizing, apply the stick solder at the quirk between edge of fitting and wall of tube when, if the precautions indicated have been taken, the solder will be seen to seep into the joint no matter what position it is in. Stop when solder floods up on the edge, and allow to cool before disturbing. Surplus flux should be wiped off while the joint is warm.



PIPE: JOINTING BRASS & COPPER. Fig. 16. Capillary joint being made on an "Ideal" fitting. See also page 210.
Ideal Boilers and Radiators, Ltd.

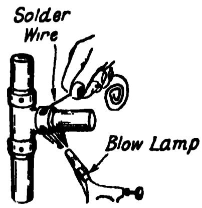


Fig. 17. Making a "Sidex" joint by applying solder to touch-holes; joint warmed by blow-lamp.
Fyffe, Dundee.

For the type with touch-hole provided, the solder is applied at that point instead of at the edge. Fig. 16 illustrates the method of making capillary joints with stick of solder and blowlamp on an "Ideal" fitting. *See also* illustrations in page 210.

Fig. 17 shows the joint known as "Sidex" being made by applying the solder to touch-holes.

Fig. 18 is a conventional section and elevation of the Yorkshire capillary fitting with a ring of solder within the socket. Recently the range of these fittings has been increased and developed for sanitary work. Fig. 19 illustrates the traps, waste, ventilation pipes and fittings for a range of wash bowls. The fittings are catalogued up to 2½ in. diameter.

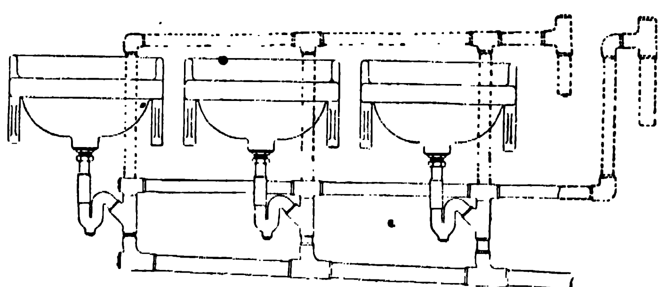


Fig. 19. "Yorkshire" capillary fittings applied to waste pipe work. Alternative methods of connecting air vent pipes are indicated by dotted lines

F. COMPRESSION JOINTS

As previously indicated, copper tubes of light gauge are more than strong enough to withstand ordinary working pressures. It is not practicable, however, to form threaded joints on this comparatively soft and thin metal. Many joints have been devised to permit the tube to be connected by means of compression unions, made of high quality brass or gunmetal.

Typical Jointing Systems. There are many special joints on the market; some require special tools to open and prepare the pipe ends for entering into contact with the compression fittings. Others need only two suitable spanners to form a watertight joint.

Fig. 20 shows the section of a well-known form of the first-mentioned type. Two holed plates and punches or drifts are

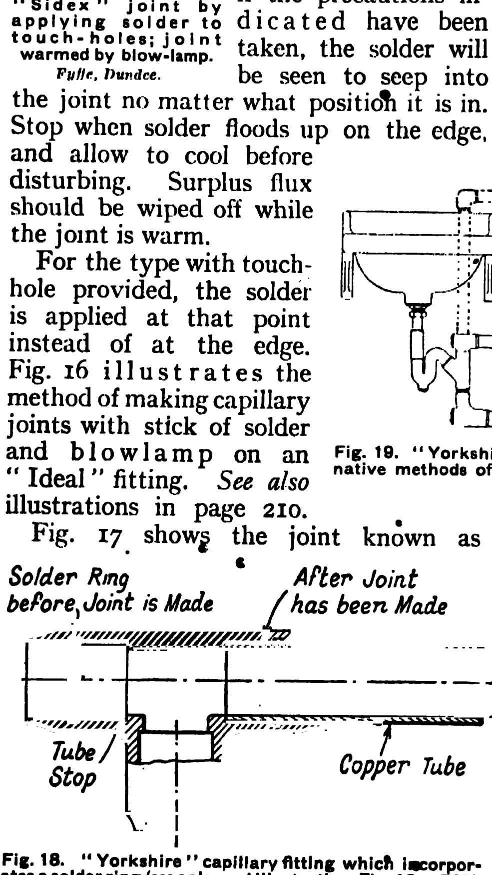


Fig. 18. "Yorkshire" capillary fitting which incorporates a solder ring (see enlarged illustration, Fig. 13, p. 762).
Yorkshire Copper Works, Ltd.

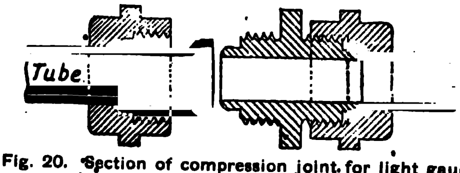
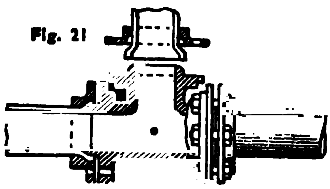


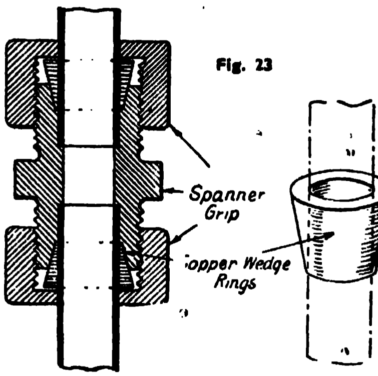
Fig. 20. Section of compression joint for light gauge copper pipes up to 2 in. diameter. Special tool is required to open pipe ends.

Fig. 21



PIPE: JOINTING BRASS & COPPER. Fig. 21 (above). Compression joint for tubes 2½in. to 8 in. in diameter, applied in a similar way to fitting of Fig. 20. See text below.
Fyffe, Dundee.

Fig. 23 (right). "Kontite" joint, in which wedge cone ring is pressed into wedge cavity between fitting and pipe wall. (*Kay & Co., Engineers, Ltd.*)



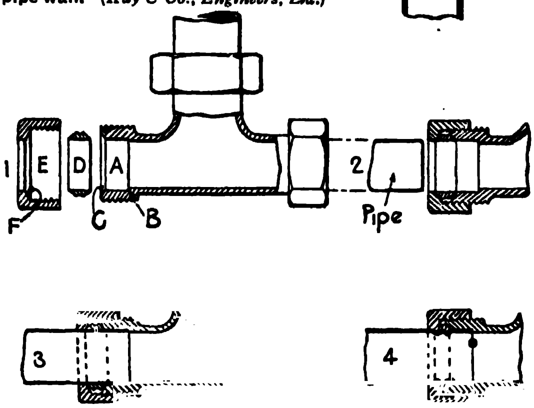


Fig. 22. Joint having compression ring. (1) The "Instantor" Union dismantled to show: A, socket; B, distance stop; C, seating for ring; D, compression ring; E, coupling nut; F, nut shoulder. (2) Union coupling with pipe ready for entering and compression ring in place. (3) Joint assembled by inserting pipe through nut and ring to abut stop. (4) Joint completed by screwing nut ¾ to one complete turn.
Fyffe, Dundee.

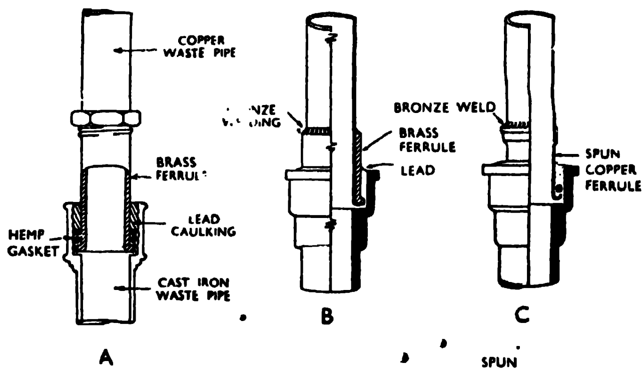
cap couplings, flanges and bolts are used. This type is listed for pipes 2½ in. to 8 in.. diameter. The special tools for preparation of tube ends can be hired if desired.

Fig. 22 illustrates the use of another principle. This type requires only to have the ends of the tube slipped into the fitting. On tightening it up, a grooved ring is compressed into the walls of the tube to grip it. It is essential that the tube shall be of a gauge to suit the fitting, and fittings must be ordered to suit the gauge of tube being used. For instance, 18 gauge tube would not enter a 19 gauge fitting; and a 19 gauge tube in an 18 gauge fitting would be too loose and would not tighten up properly.

In the type of joint which is shown by Fig. 23, a wedge-shaped cone-ring is pressed into the wedge-shaped cavity between the fitting and the wall of the pipe, on tightening up the union fly-nut.

required to bell out the tube ends to the form shown. The ball end of the brass nipple and the recess in fly-nut are ground in together so that when tightened up the copper edge is nipped between the two and so forms a metal to metal watertight joint.

Fig. 21 shows the application of a similar principle to large diameter pipes. Instead of being drawn up by screw-



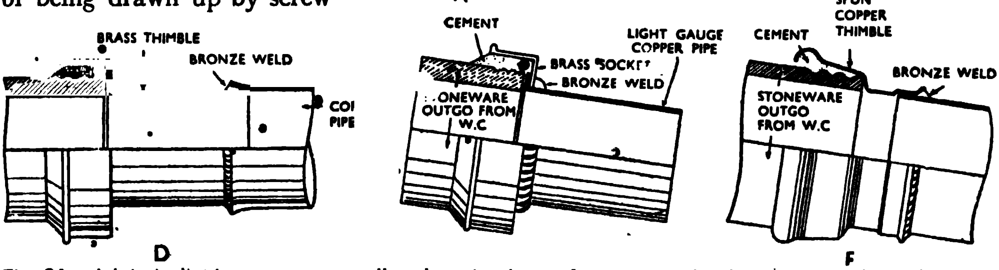


Fig. 24. Joints to light gauge copper soil and waste pipes : A, copper waste pipe to c.i. socket ; B, copper soil or vent pipe to c.i. drain ; C, alternative joint to B ; D, stoneware outgo of w.c. or stop-hopper to copper pipe ; E and F, alternative joints to D.
Copper Development Association.

This fitting allows a variation of two gauges. Fittings such as bends, tees, valves, etc., have the ends fitted with the compression joints.

Essentials of a Good Fitting. A good compression fitting should be constructed of dense non-corrodible metal or alloy. It should be strong and carefully machined to fit the gauge of tube intended. The construction should be such that the waterway is not appreciably constricted. Fittings should be proof against pulling apart by the effects of frost. Finally, it should be possible to take the joint apart without destroying the fitting.

Special Sanitary Joints. A good deal of light gauge copper tube has been used recently for soil, waste and vent pipes. Local authorities issue regulations as to method of joining copper pipes to stoneware drains, iron drains, stoneware outgo of w.c. to copper, etc.

Fig. 24 gives an analysis of various joints suitable for this class of work. The various component members are indicated. *A* shows a copper waste pipe to cast-iron socket or inlet of gully trap; *B*, copper soil or vent pipe to a cast-iron drain. *C* is an alternative to *B*; *D*, the stoneware outgo of a w.c. or slop-hopper to a copper pipe. The methods shown in *E* and *F* are alternatives to *D*.

Joints for One-Pipe System. Details of these will be found in the article on One-Pipe System (Sanitation), together with an extract from the L.C.C. Drainage By-Laws applicable.

PIPE AND PIPE FITTINGS: (4) FOR GAS

By J. W. Cowan, A.M.I.H.V.E.

This article deals with pipes of all kinds for gas, and with the appropriate jointing methods. Where methods are identical with those used in water pipes or steam pipes, the reader is referred to relevant sections of other articles in this Group. Sections are: A, Gas mains; B, Service and supply pipes: (a) Iron and steel carcass pipes; (b) Lead and composition carcass pipes; (c) Light gauge copper carcass pipes. See Gas Fitting; *also* Pipe: (2), (3), and (6); and Pipe Sizing. For methods of specifying pipe fittings *see* Pipework Chart, *f.p.* 792.

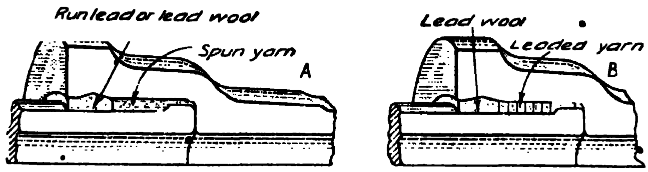
The materials and weights of which pipes to be used for the conveyance of coal gas may be manufactured, and the methods to be adopted in the fitting of gas pipes and appliances have recently been standardized by a Report of the Institution of Gas Engineers. This is published by the Ministry of Works (through H.M.S.O.) as a booklet entitled "Gas Installations," Post-War Building Studies, No. 6. The Report requires that reference be also made to a wide range of British Standards, publications of the British Standards Institution, with which the approved materials, fittings and jointing methods are required to comply.

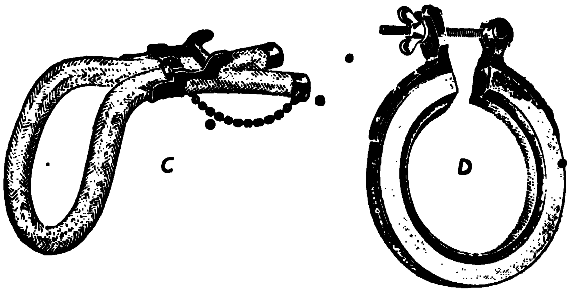
A. GAS MAINS

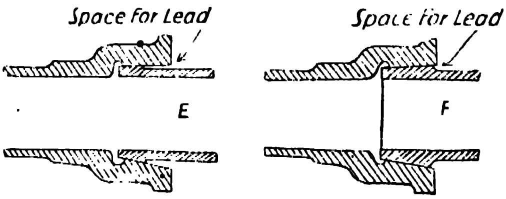
Cast-iron Pipes. Cast-iron is largely used for underground gas mains because of its mechanical strength and high degree of resistance to corrosion, in addition to the ease with which it can be cut and drilled and tapped for branch connexions. These pipes vary from 9 ft. to 12 ft. in length.

Jointing. The joints may be of the open spigot and socket type, or turned and bored, or one of a variety of special flexible joints. The open joints are made with spun yarn and caulked molten lead or lead wool. Investigation has shown that the effect of caulking run lead in order to consolidate it between spigot and socket does not penetrate deeper than about $\frac{3}{8}$ in. from the face of the joint. The use of lead wool which is caulked into a joint strand after strand, as is the yarn, ensures that the lead of a joint is solid throughout. These joints take longer to make than a run lead joint and are a little more costly, but they are generally better, and the jointing is not affected or delayed by dampness in a socket during wet weather.

A number of joints for gas mains are shown in Fig. 1, together with two asbestos packing rings, either of which should be used in preference to clay to close the front of a horizontal joint for the running-in of molten lead after the yarn has been inserted. It may be noted from Fig. 1 (*e*) and (*f*) that the rigidity of the turned and bored joints requires pipes to be laid in a perfectly straight line; and, also, that this type of joint would be unsuitable







PIPE : FOR GAS. Fig. 1. Joints and jointing for C.-I. gas mains. A and B, open lead and yarn joints. C and D, packing rings : (C) "squirrel tail" pipe jointer made of specially woven asbestos rope ; (D) pipe caulking clip for use on all main and soil pipe caulking. E and F, turned and bored joints : (E) half-bored ; (F) full-bored.

C and D: Shetack Tool Works, Ltd

where possible subsoil settlement might require some degree of flexibility in the joints. Open joints are not flexible, but each joint can be "broken" slightly during laying in order to follow the track of an easy-curving trench.

Where there is a greater curvature, outside the deflection of a separate bend, or where settlement or vibration might damage a too-rigid pipe line, some form of flexible mechanical joint must be used. Four of these are illustrated in Fig. 2. In addition to remaining gastight even when adjacent pipes are possibly 5 degrees out of alinement, these joints can all accommodate movements due to expansion and contraction.

Mild Steel Pipes. The use of mild steel for gas mains is a comparatively recent development. These pipes do not possess the corrosion-resisting properties of cast-iron, but they are made in lengths up to 50 ft., a fact which reduces jointing to a minimum ; and they are better able to withstand the stress of traffic when laid in shallow trenches. In addition, steel pipes are flexible ; each length is capable of an appreciable amount of "spring," depending upon size and length, which considerably reduces the risk of fracture from soil movement. Because of their liability to pitting under corrosive influences, steel pipes are usually wrapped in tarred hessian and the joints are similarly covered after testing.

Jointing. Both plain-end and socketed steel tubes are used. Some methods of jointing these are shown in Figs. 3, 4 and 5. The welded "bell" joint, Fig. 3 (*a*), is suitable for plain-end pipes and requires only portable oxy-acetylene welding equipment. The bell or socket is made by heating and hammering the end of the pipe. Alternatively, the joint may be butt-welded, Fig. 3 (*b*), or may be strengthened by the use of an external or internal liner, Fig. 3 (*c*) and (*d*). The inside sleeve would only be used on large pipes in which the bore restriction would be negligible.

Socketed tubes are sometimes used to assist alinement, in which case a welded

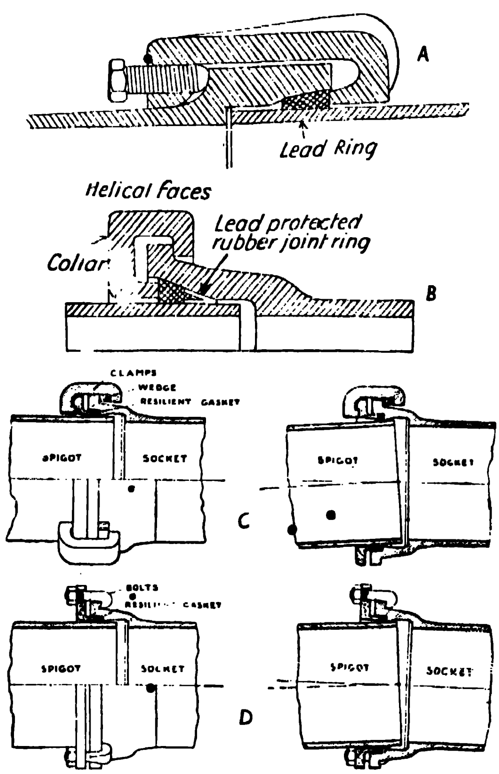
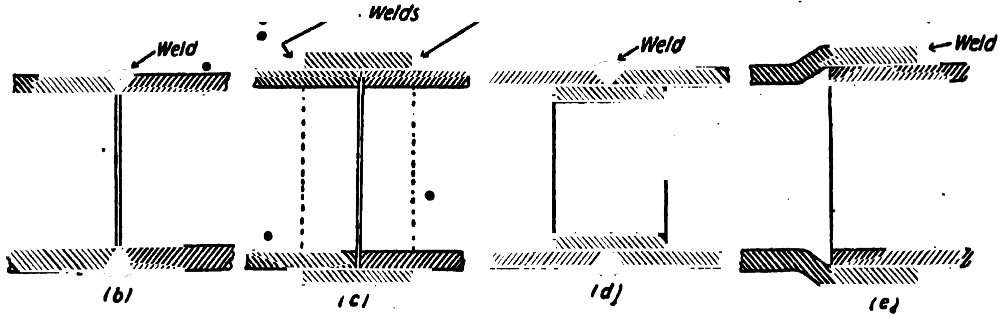


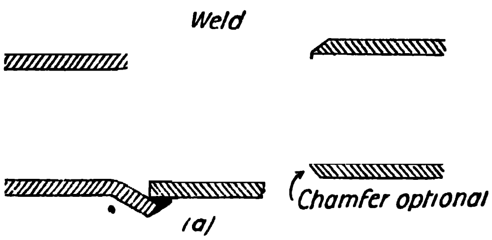
Fig. 2. Flexible mechanical joints to allow for movement and loss of alinement in pipes : A, "Stanton" joint ; B, "Stanton Wilson" joint ; C, "Staveley" flexible clamped joint ; D, "Staveley" flexible bolted joint.

joint would be made as shown in Fig. 3 (*e*) below.

Mild steel pipes can be cut more quickly with oxy-acetylene equipment than by



PIPE: FOR GAS. Fig. 3. Welded joints for plain-end and socketed steel tubes: A, welded bell joint; B, butt weld; C, welded sleeve (outside); D, welded sleeve (inside); E, welded socket.



other methods, and the same plant enables bends and other special fittings to be fabricated at site. The fabrication of a bend and pipe fittings by welding methods is described in Section E of the article Welding: (2) (*which see*). In the making of branch connexions, as for sub-mains, a cutting blow-pipe is used to make the hole, and the branch pipe is fitted into position and welded to the main.

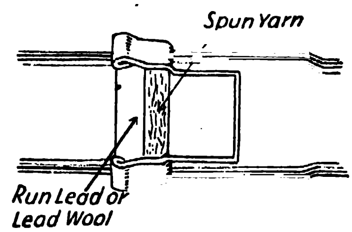


Fig. 4. Lead and yarn joint, which relieves jointing material from stress due to sagging.

Welded joints do not provide for expansion or contraction, nor do they add to the flexibility of a pipe line. The joint seen in Fig. 4 is similar to other lead and yarn joints, with the exception that the extended sleeve greatly assists alinement and relieves the jointing material of stress arising from settlement or sagging.

The Johnson coupling (Fig. 5) is designed for plain-end pipes, whether of mild steel or cast-iron. It is remarkably flexible and readily accommodates movement due to expansion. It relies upon pressure exerted by bolted flanges upon the pipe ends and rubber sleeves, and is similar in principle to the joints used for plain-end cast-iron hot water heating pipes in horticultural work.

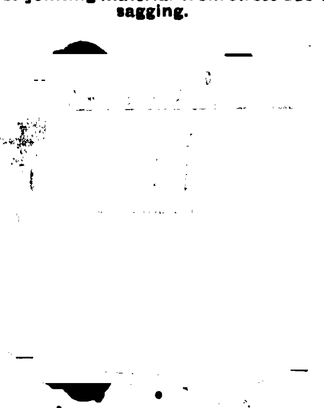


Fig. 5. "Johnson" coupling, designed for plain-end pipes, which allows for movement in expansion. Victaulic Co., Ltd.

B. SERVICE AND SUPPLY PIPES

Service Pipes. The pipe laid underground between a gas main and a consumer's premises is known as a service pipe. For a diagram showing gas main and service pipe *see* Fig. 8, p. 468. Gas fitting is dealt with under its own heading in pages 475-478. Unless of cast-iron or copper, these should be of steam weight wrought iron or Class B or C mild steel pipe.

Screwed pipes for domestic services may be of puddled wrought iron or mild steel, and should comply respectively with B.S. 788–1938 and B.S. 1387–1947. Pipes of both materials are made in three weights, light, medium and heavy. These of wrought iron are described as gas, water and steam weights, and are marked by the colours black, blue and red. The corresponding steel pipes are known as Class A, Class B and Class C, and are distinguished by colour bands of brown, yellow and green. The only differences between one weight and another lie in the wall thicknesses, and in the corresponding variation in the actual bore diameters. In wrought iron the thicknesses vary by only one S.W.G. (Standard

TABLE I.—**Standard Dimensions of Screwed and Socketed Steel Tubes**

Nominal Bore Dia.	Approx. Outside Dia.	Wall Thickness Standard Wire Gauge			Approximate Weight lb. per foot			Approximate Bore Dia. (in.)		
in.	in.	Class A	Class B	Class C	Class A	Class B	Class C	Class A	Class B	Class C
$\frac{1}{8}$	$\frac{13}{32}$	15	14	12	·25	·28	·33	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{16}$
$\frac{1}{4}$	$\frac{17}{32}$	15	14	12	·35	·39	·48	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{11}{32}$
$\frac{3}{8}$	$\frac{11}{16}$	15	13	11	·46	·58	·70	$\frac{17}{32}$	$\frac{1}{2}$	$\frac{7}{16}$
$\frac{1}{2}$	$\frac{27}{32}$	14	12	10	·65	·83	·99	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{19}{32}$
$\frac{3}{4}$	$1\frac{1}{16}$	13	11	9	·95	1·18	1·42	$\frac{7}{8}$	$\frac{27}{32}$	$\frac{25}{32}$
1	$1\frac{11}{32}$	12	10	8	1·36	1·66	2·02	$1\frac{1}{8}$	$1\frac{3}{32}$	$1\frac{1}{64}$
$1\frac{1}{4}$	$1\frac{11}{16}$	12	9	7	1·75	2·38	2·84	$1\frac{7}{16}$	$1\frac{3}{8}$	$1\frac{5}{16}$
$1\frac{1}{2}$	$1\frac{29}{32}$	11	8	6	2·33	3·02	3·54	$1\frac{21}{32}$	$1\frac{19}{32}$	$1\frac{17}{32}$
2	$2\frac{3}{8}$	11	8	6	2·83	3·84	4·52	$2\frac{1}{8}$	$2\frac{1}{16}$	2
$2\frac{1}{2}$	3	10	7	5	3·98	5·38	6·37	$2\frac{23}{32}$	$2\frac{21}{32}$	$2\frac{9}{16}$
3	$3\frac{1}{2}$	10	7	5	4·70	6·35	7·54	$3\frac{7}{32}$	$3\frac{5}{32}$	$3\frac{1}{16}$
$3\frac{1}{2}$	4	9	7	5	6·00	7·29	8.66	$3\frac{11}{16}$	$3\frac{5}{8}$	$3\frac{9}{16}$
4	$4\frac{1}{2}$	9	7	5	6·83	8·27	9·85	$4\frac{3}{16}$	$4\frac{5}{32}$	$4\frac{1}{16}$
5	$5\frac{1}{2}$	—	7	5	—	10·26	12·21	—	$5\frac{5}{32}$	$5\frac{1}{16}$
6	$6\frac{1}{2}$	—	7	5	—	12·30	14·63	—	$6\frac{5}{32}$	$6\frac{1}{16}$

For detailed information see B.S. 1387-1947.

Wire Gauge) but, as is shown in Table 1, above, there is a wider difference between the weights of steel tubes. Pipes of Classes B and C, which correspond in wall thickness and actual bore diameter with the gas and steam weights of wrought iron pipe, differ by two S.W.G. Class A pipes, from one to three gauges lighter than Class B, is a new light-weight tube, not made in sizes over 4 in. nominal bore. Whatever the material or weight of a tube, the external diameter is constant in each nominal bore size : the variation of actual bore with wall thickness renders the bore diameters wholly nominal, as seen in the last three columns of Table 1. These pipes are normally formed from strips of metal, butt welded in sizes to 3 in. nominal bore, and lap-welded in larger sizes, but solid-drawn (seamless) tubes are also widely used for the same purposes. These tubes are hydraulically tested after manufacture as follows :

Wrought Iron	*lb. sq. in.*
Gas pipes, all sizes	500
Water pipes, all sizes	600
Steam pipes, up to 2 in. diameter	700
Steam pipes, over 2 in. diameter	1,000

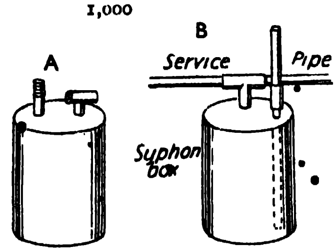
Mild Steel	*lb. sq. in.*
Class A, B, C—All Sizes up to 6 in. diameter	700

In addition, tubes of all weights to be used for gas work must be further tested by internal air pressure of 100 lb. per sq. in. while the pipe is immersed in water.

Reference should be made to Gas : (3) Town's Gas Utilization, p. 468, for notes on the alinement of service pipes and the use of " receivers " or " siphon boxes." Two views of such fittings are shown in Fig. 6. The lower end of the vertical outlet or suction pipe, seen in broken lines in Fig. 6 (*b*), can be sealed by pouring a few inches of water into the cylinder. The moisture of condensation is pumped out through the suction pipe.

Installation Work. All gas pipes on a consumer's premises from the outlet of a meter are known as supply pipes or internal installation pipes. There are three kinds of pipes in general use for such work, namely, (*a*) iron (or steel) pipes ; (*b*) lead and composition (compo) pipes , and (*c*) light gauge copper pipe.

(A) Iron (or Steel) Installation Pipes. Screwed mild steel gas pipes of dimensions given in Table 1 are largely used. The fitting of this pipe is similar to the fitting of screwed tubing for other purposes, as for heating and hot water work. Gas pipes are cut preferably by means of a hacksaw, to ensure freedom from the internal burrs made by most wheel pipe cutters—a point of primary importance in small bore pipes —and the same dies as for other purposes are used to cut the threads. Note that a joint may be made gas-tight by coating the male thread with paint or jointing compound without the use of hemp, even when parallel-tapped

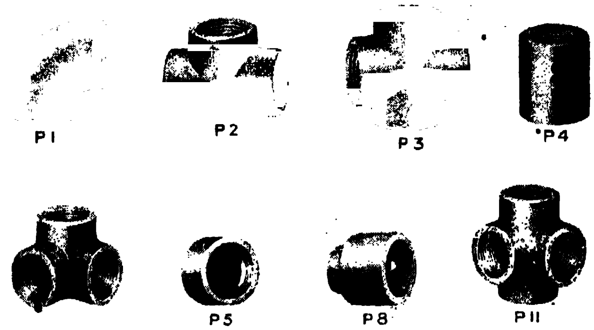


PIPE FOR GAS. Fig. 6. A, receiver or siphon box, as fitted at lowest points in gas mains and service pipes to collect condensation ; B, method of connexion to service pipe. *See also* Fig. 8, page 468.

fittings are used; that sleeve pipes are generally unnecessary; and that gas pipe brackets need not permit of the lengthwise movement to which alternate expansion and contraction subjects hot water pipes.

Screwed pipe fittings are discussed in greater detail in Pipe: (6). Gas fittings are in all respects similar to other screwed fittings. Both mild steel and malleable cast-iron are used, although, in view of the low pressure and the absence of active corrosion in internal work, there would seem to be little to commend the stronger but more crude and clumsy steel fitting.

Malleable fittings may be of either "black-heart" or "white-heart" malleable cast-iron Both are manufactured in the "plain" pattern, without band or bead at the outlet, which is generally preferred for gas work because of the better appearance and the absence of real need of reinforced outlets. A number of plain pattern pipe fittings are shown in Fig. 7.



PIPE: FOR GAS. Fig. 7. "Plain" pattern (without bead) malleable fittings for iron or steel carcass pipes: P1, round elbow P2, equal T; P3, equal cross; P4, socket; P10, side outlet elbow; P5, cap; P8, concentric reducing socket; P11, side outlet T.
Ideal Boilers and Radiators, Ltd.

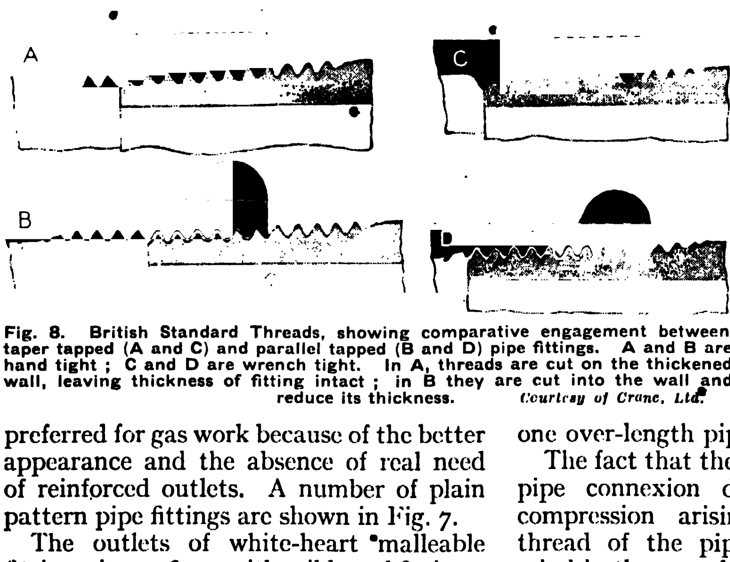


Fig. 8. British Standard Threads, showing comparative engagement between taper tapped (A and C) and parallel tapped (B and D) pipe fittings. A and B are hand tight; C and D are wrench tight. In A, threads are cut on the thickened wall, leaving thickness of fitting intact; in B they are cut into the wall and reduce its thickness. *Courtesy of Crane, Ltd.*

The outlets of white-heart malleable fittings, in common with mild steel fittings, are invariably tapped with a parallel thread, in contrast to the tapered tappings of all black-heart fittings. The essential differences between the two methods are shown in Fig. 8. The metal-to-metal engagement at all points between the tapered thread on a pipe and a taper-tapped black-heart fitting is to be seen at Fig. 8 (*a*) and (*c*). Fig. 8 (*b*) and (*d*) show the lack of engagement which must obtain within any parallel-tapped fitting in the absence of distortion.

In practice, the fitting is expanded near the outlet by the tapered pipe thread, but it is principally on account of this lack of engagement that hemp is considered so necessary in screwed pipe work. These diagrams also show how the additional thickness of metal behind a tapered tapping provides accommodation for possible over-length threads on a pipe, and enables them to project into the clearance beyond the end of the female thread. It will be noticed that parallel threads are cut into the wall of the fitting; they shallow out necessarily towards the inner end and cannot, therefore, accommodate even one over-length pipe thread.

The fact that the soundness of a screwed pipe connexion depends entirely upon compression arising from the tapered thread of the pipe should be borne in mind in the use of nipples. The use of the "parallel" nipple, Fig. 9 (*a*), is always to be deprecated. The pressure-tightness of

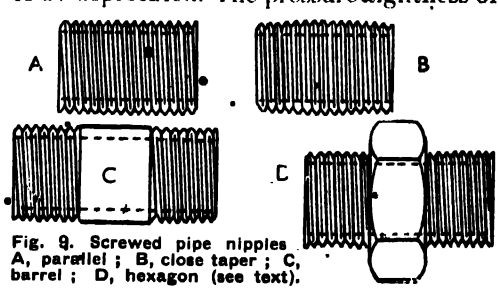
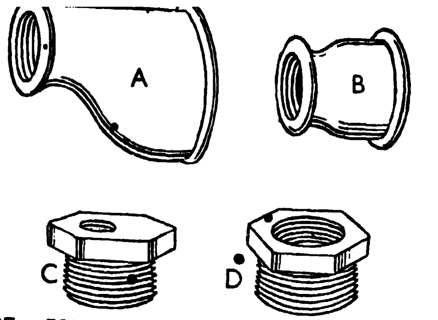


Fig. 9. Screwed pipe nipples A, parallel; B, close taper; C, barrel; D, hexagon (see text).



PIPE : FOR GAS. Fig. 10. Reducing fittings for service pipes : A, eccentric reducing socket ; B, concentric reducing socket ; C, eccentric bush ; D, concentric bush.

any such connexion must depend upon the fittings so assembled abutting each other squarely, and having chamfered faces between which to compress a hemp or other packing, which would alone ensure pressure-tightness.

Wherever possible one of the other three should be used. All of them have tapered threads with which to make a sound and permanently rigid connexion. The " close taper " nipple, Fig. 9 (*b*), and the " barrel " nipple, Fig. 9 (*c*), are screwed from pieces of tube. The " hexagon " nipple, Fig. 9 (*d*), is invariably of malleable cast iron. This pattern can be tightened easily because of the hexagon, and is the only type of nipple made in reducing sizes—that is, with one end of a smaller pipe-size than the other.

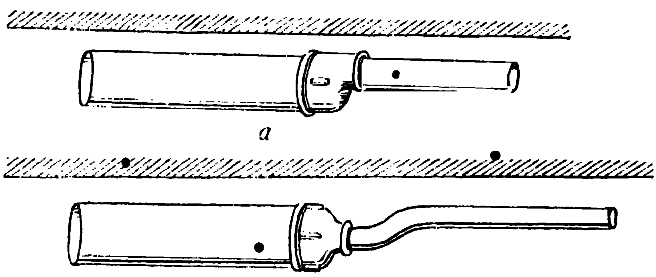


Fig. 11. Reducing sockets on pipes : A, eccentric fitting used to maintain constant spacing from wall ; B, concentric fitting, requiring unsightly offset to maintain spacing.

The correct use of reducing fittings, to be seen in Fig. 10, is also worthy of notice. As in other pipework, the eccentric pattern makes for a better appearance with both horizontal and vertical gas pipes than is possible when concentric reducing fittings are used. Normally, in gas work, the flat side of the eccentric reducer can be used to maintain a constant spacing between a reduced pipe line and a wall, as shown in Fig. 11 (*a*). Only in large installations and in the absence of dehydration is it necessary to maintain a straight underside to facilitate the draining away of condensate, in which case horizontal pipes would be alined to drain back towards the meter, or to other points at which receivers would be fitted.

It is important to note that the lower end of a vertical steel or iron gas pipe should not terminate in a bend or elbow. Even when gas has been dried or dehydrated there would remain the risk of chokage at the bend from flaking scale within the pipe. To ensure access for inspection and in case of partial chokage, all vertical pipes should at least be fitted with a plugged tee as shown in Fig. 12. Alternatively, when the pipe is in an inconspicuous position, a short length of pipe with a cap on the lower end may take the place of the plug to provide a pocket for scale or possible condensation.

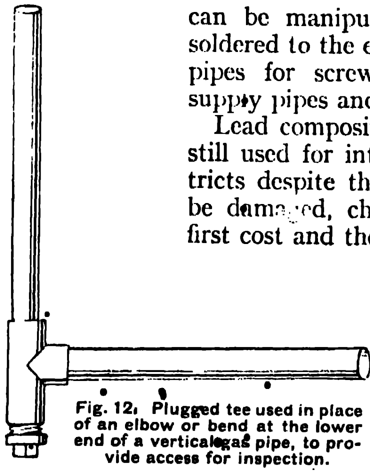


Fig. 12. Plugged tee used in place of an elbow or bend at the lower end of a vertical gas pipe, to provide access for inspection.

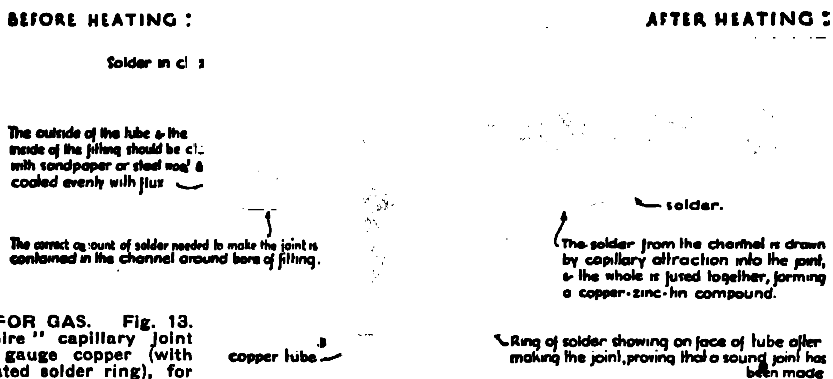
(B) Lead and Composition Carcass Pipes. Lead pipe is almost invariably used to connect small and medium sized meters because of the ease with which it can be manipulated. Brass unions are soldered to the ends of the lead connexion pipes for screwing to the service and supply pipes and meter connexions.

Lead composition or " compo " pipe is still used for internal work in many districts despite the ease with which it can be damaged, chiefly because of the low first cost and the speed with which it can be fitted. It is similar to lead in appearance, but is made of a lighter and cheaper alloy (*see* Composition Pipe). It is supplied in coils weighing from 56 lb. to 1 cwt., and in

lengths varying with size from 80 ft. to 250 ft. The screwed brass nipples used for connexion to fittings may be soldered on by the use of a copper bit or by means of a "blown" solder joint.

(C) Light Gauge Copper Carcass Pipe. During recent years light gauge copper tube has been used extensively for gas work. In many districts it has been adopted exclusively for carcass work and service pipes, for which it is eminently suited by reason of its glass-smooth bore and freedom from corrosion. In cost per installation it is fairly comparable with steel pipe despite the higher cost of copper.

Fig 16, in page 754, shows a solid drawn copper fitting which is soldered to the pipe, after cleaning and fluxing, by heating the joint and applying a solder wire to the mouth of the socket. (*See* also p. 210 for further illustrations.) In Fig. 13 (below) a fillet of solder is provided within the socket of a hot-pressed brass fitting. After cleaning, fluxing and assembling, this fitting need only be heated until capillarity draws the then molten solder out of the groove to complete the joint. This requires only one hand to hold the blowlamp—a point to be appreciated in many awkward corners in which gas pipes have to be fitted.



PIPE: FOR GAS. Fig. 13. "Yorkshire" capillary joint in light gauge copper (with incorporated solder ring), for carcase pipe (see *also* Fig. 1, p. 210, which shows cross-sectional diagram of this fitting).

This is largely due to reduced labour charges, because of the ease with which it can be bent and jointed. Although in the smaller sizes the wall-thickness is only 0.048 in. it is very considerably stronger than compo pipe and is much less easily damaged.

The specified air-test pressure for non-ferrous tubes is only 100 in. water gauge (3.6 lb. per sq. in.), but the pressures of hydraulic destruction tests are of the order of 5,000 lb. per sq. in.

In the jointing of these tubes compression joints are used to some extent, but they are heavy and bulky, and capillary solder joints are generally preferred for gas installations. Solder fittings are but little heavier than a similar length of light copper pipe and have the great advantage that they do not normally project more than ⅛ in. or so beyond the line of the pipe.

These fittings are discussed in greater detail in the preceding article Pipe: (3) Jointing Brass and Copper.

Owing to the circumferential clearance between pipe and socket being usually less than 0·002 in. in these joints, the solder penetrates the inter-crystalline boundaries of both fittings and takes (*a*) copper, and (*b*) copper and brass into solid solution. Because of this, solder joints are not dependent upon a simple tin-lead solder but upon much stronger alloys composed of (*a*) copper-tin-lead, and (*b*) copper-tin-lead-zinc; the latter is harder because of the zinc absorbed from the brass.

One of the most attractive features of the solder fitting is that the joints need not be made at the time the pipes are fitted. It is often convenient to assemble the greater portion of the work with the joints merely cleaned and fluxed, and to do the soldering later with one lighting of the blowlamp. It may be noted that this method ensures that each length of pipe must be adequately supported by brackets, and quite independently of the joints.

PIPE AND PIPE FITTINGS: (5) FOR PETROL, OIL AND COMPRESSED AIR

By J. W. Cowan, A.M.I.H.V.E.

Information for the Pipe Fitter on the pipes and fittings suitable for these services. Since in some respects the materials and methods are identical with those for other pipework, the reader should refer to appropriate articles in this Group for further general notes. **See *also* Pipework ; Screw Cutting.**

Information is given here about the fitting of pipes for petrol and oil services, and those for compressed air lines. Since much of the procedure is similar to that for other pipe fitting, reference is made to the relevant articles elsewhere in this Group.

A. PETROL PIPES

Petrol is perhaps the most troublesome of all liquids for which pipe lines are required. By reason of its volatility and high degree of inflammability, leakages can be exceedingly dangerous, and no liquid is more searching with regard to the other-than-perfect pipe connexion.

Copper pipes with sleeve type compression or capillary soldered fittings, are used on most petrol pipe lines, where small sizes of feed pipes are required. This applies particularly to feeds on internal combustion engines since copper, when annealed, will withstand vibration without fear of fracture.

Since it is not used at high pressures, ordinary steam weight mild steel pipe and the normal fittings are suitable, but the joints require more than usual care.

All that is said of clean-cut threads and cleanliness with regard to screwed joints for compressed air (*see later*) applies imperatively to petrol connexions. The "receder" type of die stock will greatly assist the accurate cutting of threads. For further notes *see* Screw Cutting.

Jointing Compounds. It is equally necessary to avoid the warmth of friction in making the joint, and for this reason it is advisable to use a better than usual jointing compound. This should be composed of litharge (lead monoxide), a yellowish-brown powder, and glycerine, and should be mixed to the consistency of enamel in small quantities as required. This is fairly expensive and to avoid waste should be kept in an airtight screw-capped glass or stoneware jar. Its value lies in its rapid hardening within the joint, where it fills all irregularities between the threads through which the petrol would assuredly find a way. This jointing paste (composed of litharge and glycerine) differs from the white or graphitic compounds used for other work in an important detail: these latter are largely lubricants and do not harden.

B. OIL PIPES

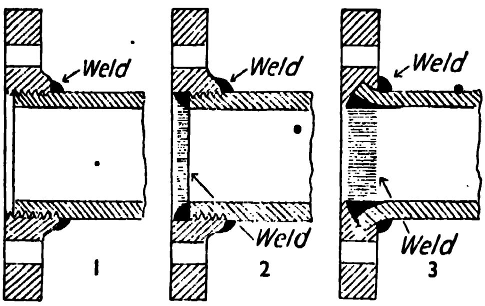
In deciding the method to be adopted in fitting pipes for an oil service, much will depend upon the temperature and pressure of the oil. For the connexion between an oil fuel tank and the burner of a central heating boiler, special material would be unnecessary. Ordinary mild steel or copper pipe and the usual ranges of fittings would be used, and it would be sufficient to assemble the work with normal attention to detail.

In oil refineries, where higher temperatures and pressures would be encountered, welding has replaced much screwed pipe work. For small connexions specially heavy malleable iron fittings are made. Usually these have American threads, somewhat longer than normal, which of course require that American dies be used in the stocks. For hot oil-fuel lines required to deliver oil at temperatures and pressures of, perhaps, upwards of 250° F. and 100 lb. per sq. in., these heavier fittings and longer threads would normally be used ; but screwed joints are reduced to a minimum and welding is now largely used towards this end.

Heavy Duty Lines. For heavy duty oil lines, as for solid injection to a Diesel engine, pressures from 2,000 lb. to 10,000 lb. per sq. in. necessitate heavy walled solid drawn tubing and welded or machine-faced flange connexions. The flanges are normally shrunk on to the pipe by being screwed on at a red heat while the pipe is cold. Even for comparatively low pressures this would be followed by expanding the pipe into the threads of the flange, although it is doubtful whether that is necessary. In large pipes the shrinking is frequently

followed by single or double welding.

In single welding, a fillet weld is made between the shoulder or boss of the flange and the pipe to cover possible weakness left by screwing, as shown in Fig. 1. In double flange welding the pipe is left $\frac{3}{8}$ in. to $\frac{1}{2}$ in. short of the face of the flange and the second weld is made inside, as shown



PIPES : FOR PETROL, OIL, AIR. Figs. 1, 2 and 3. Flange welds on heavy duty oil lines : (1) single flange weld ; (2) double flange weld ; (3) special high pressure flange weld.

in Fig. 2. Screwing assists the alinement of flanges but is not indispensable. Fig. 3 shows a high pressure flange joint in which the pipe end is expanded into a specially prepared socket in the flange prior to welding.

Specially heavy fittings are made from solid steel forgings for hot oil up to 900° F. and 1,200 lb. per sq. in., but these are not recommended for lines subject to shock.

C. COMPRESSED AIR PIPES

Pipes for compressed air lines for light work, as for foundries, sand-blasting, paint-spraying and small pneumatic tools, are usually of steam weight mild steel. For heavier duties, a heavier quality of solid drawn (seamless) steel pipe would be used.

The ordinary ranges of malleable fittings are quite suitable for light work, but for high pressures the stronger wrought-iron fittings would be used, especially where the line might be subject to vibration or concussive shock. Welding is frequently adopted for large pipes; welded flanges are then used for the connexion of filters and other fittings which may need to be dismantled from time to time.

There are several points to which particular attention should be paid in the erection of compressed air lines.

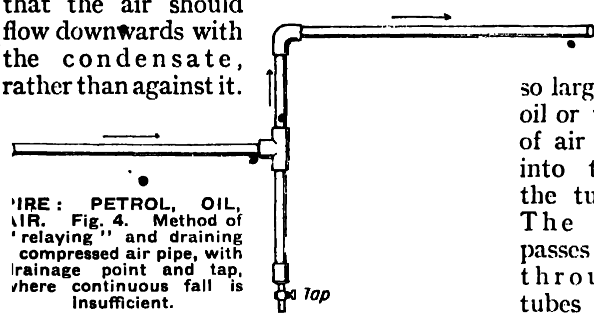
Screwing. First, it is essential that the screwing dies be in good condition, and that sufficient care is used and cooling oil employed to ensure that the thread is accurate, clean-cut and unbroken. However much a liberal use of hemp and jointing compound may serve to make good the deficiencies of worn dies and a shallow thread in the making of screwed joints for other purposes, slipshod methods and tinkering remedies will avail little against air. In recognition of this, first class practice in heating and hot water work requires that these pipes be given an air test for soundness of connexions, in addition to the usual hydraulic tests for other purposes.

Secondly, in screwing a fitting to a pipe, it is essential that this be done without undue haste, and without dust or grit on the threads. Owing to the considerable amount of bearing surface between the roots, slopes and crests of the threads, the heat of friction would cause both threads to expand and to meet in metallic contact sooner than they would in the absence of heat, an action greatly assisted by the presence between the threads of dust and grit from a building site. Such a joint would be sound at the time of making, could a test be applied immediately ; but, with the dissipation of the heat, a proportionate contraction of both pipe and fitting would take place and the joint would no longer be pressure-tight. In screwed and flanged pipe work this trouble is remedied by the use of a pipe expander, somewhat similar to those used for boiler tubes. The principal purpose of the graphitic or other jointing compound with which the male threads should be coated is to lubricate the joint during making and so reduce friction.

Pipes are tested for leakage of compressed air by watching a sensitive gauge while the line is under pressure but not in use, and leakages are located by painting suspected joints with soapy water, through which leaking air will bubble.

Alinement. Thirdly, the alinement of every section of an air line is of primary importance. Owing to the presence of both water vapour and oil in compressed air, the former from atmospheric humidity and the latter from the air compressor, air lines are akin to steam pipes and should be equally free from dips or traps in which condensate would collect. Every section of an air line should drain towards a drainage point: long pipe lines may require several of these, all located at low

points and fitted with a short length of pipe and a tap for the removal of moisture. As in steam work, good practice requires that the air should flow downwards with the condensate, rather than against it.



PIPE: PETROL, OIL, AIR. Fig. 4. Method of "relaying" and draining compressed air pipe, with drainage point and tap, where continuous fall is insufficient.

For this reason air pipes should have a continuous fall of not less than ½ in. in 10 ft. in the direction of flow. Where structural considerations prevent this, the pipe must be "relayed" and drained, as shown in Fig. 4.

Filters. In addition to line drainage, many of the operations for which pneumatic tools are used require the air to be filtered for the removal of remaining oil and moisture. Fig. 5 illustrates a suitable fitting which would usually be placed as close as possible to the hose connexion points where, of course, the air is coolest and least able to contain moisture. The fitting illustrated operates as follows, in common with similar filters designed for horizontal pipes.

The arrows indicate the direction of flow. The velocity of air entering the filter is reduced on the inlet side, and any oil or water in the stream is precipitated on to the top surface of the central cone and drains over the edges to the collecting chamber below. The area of the surface of the cone is so large that there is no tendency to lift oil or water, as the direction of the flow of air is diverted vertically towards and into the top of the tubes shown. The air then passes downward through these tubes and throws any remaining oil or water through the perforated inverted cone (which is so designed as to form a trap or seal), as the direction of flow is again changed upwards to the outlet. Oil or water, which are usually in combination, are therefore separated from the air at two separate and distinct points in this cycle of events, rendering the process of elimination very efficient. Provision is also made for a drain pipe to be connected to the collecting chamber, which would, of course, be controlled by means of a valve or cock.

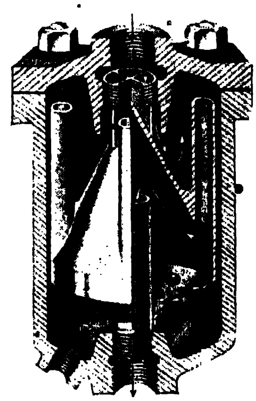


Fig. 5. Air filter for removal of oil and moisture from compressed air pipe. *Newman Hender & Co., Ltd.*

PIPE AND PIPE FITTINGS: (6) IRON AND STEEL PIPES FOR HOT WATER AND STEAM

By L. C. C. Rayner, A.I.E.C.

This article deals with pipes from the point of view of the Heating Engineer and the Hot Water Fitter. Though much of the information given applies also to gas pipes, the reader should refer to Pipe: (4) for specific notes about pipes for gas. Sections of the present contribution are: A, Pipe qualities; B, Pipe fittings; C, Joints to iron and steel pipes; D, Fitting and fixing. See *also* Pipe Sizing for Hot and Cold Water Supply Services; *and* Pipework.

Steel and wrought iron piping is extensively employed for heating, hot water supply, gas, steam, condense and cold water supply, and occasionally for waste and soil stacks and branches. These pipes are made from strips of either wrought iron or steel and consequently have a longitudinal seam. This may be either a butt or a lap joint. Tubes up to 2 in. nominal bore usually have a butt joint and those above this diameter a lap joint. In the process of manufacture, strips of mild steel or wrought iron of the right width are made hot and pushed through grooved rollers. Successive rollers bring the strips into the necessary cylindrical shape until the edges butt or overlap as required. Then, with the strip at welding heat and a mandrel inside, the strip is passed through the final set of rollers, which force the edges together so that they are completely welded.

A. PIPE QUALITIES

For normal plumbing and heating purposes, tubes are made in three grades: class A, which is painted brown externally; class B, painted yellow; and class C, painted green. The diameters, thicknesses and weights of these tubes are given in Table I page 759, under the heading Pipe: (4). In all cases the bore is only nominal, the actual dimension never agreeing with it. The outside diameter for each size remains the same whatever the grade. As the wall thickness varies the internal diameter must vary accordingly for the same nominal size. The outside diameter must be kept the same since the same fittings may be used with pipes of different quality.

Classification under the letters A, B, C, is recent and replaces the old nomenclature of gas, water and steam weight, approximately indicative of the suitability of a given wall thickness for any purpose. The new grades have thinner walls than the old, class A being so thin that it will not take B.S. pipe thread.

The application of the different new grades was not in 1948 standardized, but it was probable that class B pipe would be used for most purposes inside buildings and class C outside. Steel piping is not suitable for conveying water of condensation, since it is quickly corroded. Here wrought iron tube may be used or, better, copper or cast-iron pipe.

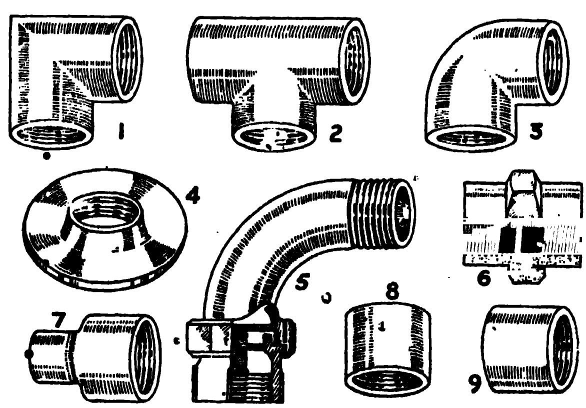
Finish and Protection of Pipes. For heating and gas work in buildings the piping usually has as a finish only the distinguishing colour mentioned above. When used for hot or cold water supply, galvanized piping is most usual. This, again, is a regulation of a number of water authorities. The galvanizing process consists in making the pipe hot and dipping it in a bath of molten spelter (mostly zinc), and allowing the surplus to drain off. The pipe is cleaned chemically before dipping. The galvanizing should have a silvery lustrous uniform appearance and should be completely free from white spots. Pipes are occasionally given a coating of bitumen or Dr. Angus Smith's solution. These finishes are intended for gas or cold water pipes to be buried in the earth. A further protection for such purposes is a wrapping of bitumenized felt.

Although the term "wrought iron pipe" is often heard, genuine wrought iron pipe is seldom met with. Most piping is made from low grade steel. Wrought iron is almost pure iron and has a tough fibrous nature; it is generally more resistant to corrosion.

It is more expensive than steel pipe and hence is normally employed only where corrosion is likely to be encountered. The conveyance of condensation is one instance; another is where pipe is to be buried in ground known to have or likely to have a deleterious effect on the pipe metal.

Before steel or wrought iron pipe is used it should be examined. Each length should be straight. The seam should be looked over, since probably the most usual trouble encountered is a "split" seam. In the case of such defect the seam does not actually split but has never properly been made. It shows as a rule only when the pipe is put under test, but an examination should reveal it before the pipe is used and so save a lot of unnecessary work. The length of pipe should also be looked through.

Very often pieces of metal scale off inside, due to the heating and cooling during manufacture. If these are left they restrict the bore and probably lead eventually to a complete stoppage, by affording a lodging place for any foreign matter in the pipe.



PIPE : IRON AND STEEL, FOR HOT WATER AND STEAM. Fig. 1. Wrought fittings for steam, water, and gas : (1) square elbow; (2) tee; (3) round elbow; (4) flange; (5) M and F union bend (see *also* Fig. 10, p. 799); (6) socket union; (7) diminished socket; (8) cap; (9) plain socket. (For methods of specifying, see Pipework Chart facing page 791.)
Crane, Ltd.

B. PIPE FITTINGS

Fittings are used to join lengths or change direction for branches, etc. There are three types, known as wrought iron, malleable iron and cast-iron. The last is seldom used with screwed joints, except for sprinkler work. Wrought iron fittings are again miscalled, being made from pig iron (*see* page 815). They are of welded construction, and a number of various types available are shown in Fig. 1. Their use is confined mostly to steam and gas pipe lines (*See* Pipework Chart, *facing page* 791, for method of specifying pipe fittings.)

Malleable iron fittings are now employed far more than any other type.

British Standards have been prepared for these fittings, one for whiteheart and the other for blackheart fittings, that is for the two different processes used for producing malleable iron.

Malleable fittings as their name implies are slightly malleable and can be expanded or stretched. They start as hard white cast-iron fittings. They are put into ovens with various oxides and heated to a high temperature for a number of days. During this process the carbon in the cast-iron is oxidized to a varying depth. The soft, almost pure iron thus formed gives these fittings their malleable property. The depth to which the change takes place will govern the degree of malleability. Most fittings have a bead round each outlet to strengthen them, although for use with gas pipes they can be obtained without the bead.

The threads on fittings are parallel, and thus, in the process of screwing up the joint, the taper threads on the pipe can distort the fittings to form a tight joint. Malleable fittings can be obtained in a considerable range of types and sizes. A little practice is necessary to screw in the pipe sufficiently to make a tight joint without excessively distorting the fitting. The defect most likely to occur with these fittings is a blowhole which may be formed during the casting process. Two finishes are obtainable, black and galvanized. In the first the fittings are given a coat of colourless lacquer, while the second finish is similar to that on galvanized piping.

TABLE I—**British Standard Pipe Threads. Schedule of Sizes.**

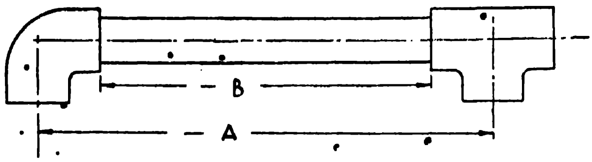
1	2	3	4	5	6	7	8	9	10	11
Nominal bore of tube	Approx. outside diameter of black tube	Gauge diameter and definition	Depth of thread	Core diameter measured at same distance from end of pipe as the gauge diameter	Number of threads per inch	Length of thread		Distance of gauge diameter from pipe end Class 1 taper screw		
						on pipe end Min.	in coupler Min.	Standard	Max.	Min.
Inches	Inches	Inches	Inches	Inches		Inches	Inches	Inches	In.	In.
1/8	13/32	0·383	·0230	0·337	28	3/8	3/4	5/32 (0·1563)	0·18	0·13
1/4	17/32	0·518	·0335	0·451	19	7/16	7/8	3/16 (0·1875)	0·22	0·16
3/8	11/16	0·656	·0335	0·589	19	1/2	1	1/4 (0·25)	0·29	0·21
1/2	27/32	0·825	·0455	0·734	14	5/8	1¼	1/4 (0·25)	0·29	0·21
5/8	29/32	0·902	·0455	0·811	14	5/8	1¼	1/4 (0·25)	0·29	0·21
3/4	1 1/16	1·041	·0455	0·950	14	3/4	1½	3/8 (0·375)	0·44	0·31
7/8	1 7/32	1·189	·0455	1·098	14	3/4	1½	3/8 (0·375)	0·44	0·31
1	1 11/32	1·309	·0580	1·193	11	7/8	1¾	3/8 (0·375)	0·44	0·31
1¼	1 11/16	1·650	·0580	1·534	11	1	2	1/2 (0·5)	0·58	0·42
1½	1 29/32	1·882	·0580	1·766	11	1	2	1/2 (0·5)	0·58	0·42
2	2 3/8	2·347	·0580	2·231	11	1 1/8	2¼	5/8 (0·625)	0·73	0·52
2½	3	2·960	·0580	2·844	11	1¼	2½	11/16 (0·6875)	0·80	0·57
3	3½	3·460	·0580	3·344	11	1 3/8	2¾	13/16 (0·8125)	0·95	0·68
4	4½	4·450	·0580	4·334	11	1 5/8	3¼	1 (1·0)	1·17	0·83
6	6½	6·450	·0580	6·334	11	2	4	1 3/8 (1·375)	1·60	1·15

Based on B.S. 21 : 1938

A British Standard Table for pipe threads has been prepared, and a condensed form of this is here printed. Since the thread has a continuous taper, a few threads furthest from the pipe end must be imperfect. The Table does not give all the particulars in the British Standard Table (which can be had for 2/2 post free, from the B.S.I.), but only those of most use to the plumber and hot water fitter.

C. JOINTS TO IRON AND STEEL PIPES

Before making a joint on a job it is usually necessary to take measurements, since the pipe runs must finish at certain



PIPE : IRON AND STEEL. Fig. 2. Method of taking pipe measurements : A, centre to centre of fittings ; B, clear distance between fittings. See text below.

points determined by the layout of the installation. These measurements will be between fittings and/or between a fitting and a valve.

Pipe Measurements. The usual method is to take the dimensions from "centre to centre" of the fittings. This is shown by A in Fig. 2. From this dimension must be subtracted the distance between the centre and end of both fittings, giving the clear distance between them. This is shown by B in Fig. 2. Now the length of thread entering each fitting must be added, giving the overall length to which the pipe must be cut before it is threaded. This is usually known as an "end-to-end" length or measurement. If a pipe is to be cut, therefore, to a given measurement, care must be taken to ascertain whether it is a centre-to-centre or end-to-end measurement that is given.

If dimensions are being taken in, say, a boiler house in order that the necessary pipe may be cut and screwed at works, centre-to-centre measurements will be taken. These are then sketched out in the office and the end-to-end measurements calculated. These latter may then be passed on to the works in the form of a schedule giving the diameter and length of each pipe.

Offsets. When an offset in a pipe line is required, 45 deg. elbows are often employed. The length of pipe between will depend on the amount the pipe is to be set. This is given as A in Fig. 3. If this dimension is multiplied by 1·41 the length B is obtained. If twice the length of thread is added and twice the end-to-centre measurement of the fitting is subtracted, the proper end-to-end length of the pipe is found. To avoid multiplication, the elbows may be laid on two parallel chalk lines the proper distance apart on the floor, and the measurement made direct.

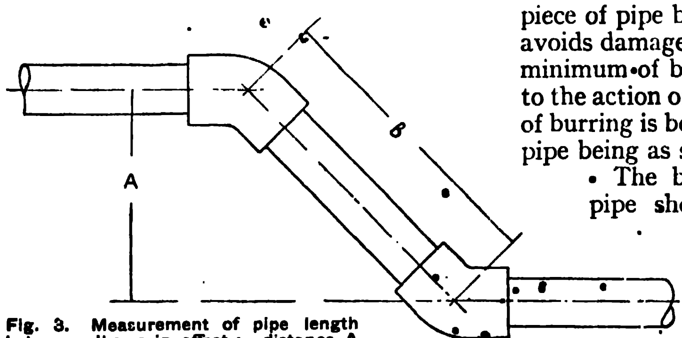


Fig. 3. Measurement of pipe length between elbows in offset : distance A (centre to centre of main pipe lengths), × 1.41 equals length B.

Cutting the Pipe. Having measured off the necessary length on the pipe it must be cut. The normal tool is the three-wheel cutter (*see* Fig. 2 page 782). This should be placed on the pipe with the wheels exactly on the mark which has been made. The handle is screwed down until the wheels bite into the metal, and then the cutter revolved round the pipe. It is essential that the cutters be held at right angles to the pipe when they are screwed up. Otherwise they try to cut two grooves, and eventually the wheels spring from one to the other, losing pieces of their cutting edges in the process. Where space is restricted it may be impossible to revolve the cutter round the pipe, and as the tool has three wheels it will cut a complete circle provided it is swung through not less than 120 deg. If space is insufficient to allow of this, a hack saw may be used.

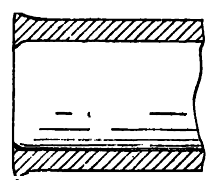


Fig. 4. Burring on end of pipe after use of three-wheel cutter. Note the consequent reduction of internal pipe-diameter.

The cutter should be operated until it is nearly through the metal, applying a little oil to the wheels from time to time. When the cut is nearly complete the cutter should be removed and the piece of pipe be broken off by hand. This avoids damage to the wheels and forms the minimum of burr inside the pipe. Owing to the action of the cutter a certain amount of burring is bound to occur, the end of the pipe being as shown in Fig. 4.

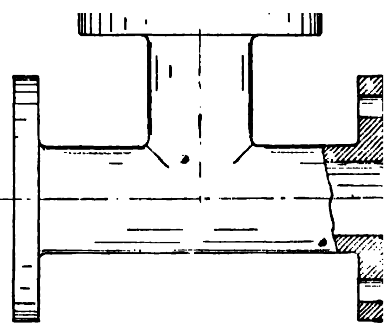
The burr on the outside of the pipe should be filed off and that inside removed with a reamer or file. The end of the pipe should then be carefully examined for cracks.

Cutting the Thread. Stocks and dies are used for putting a thread on the pipe. Two types are shown in page 933. The solid one (Fig. 2) has a separate set of dies for each pipe size, and the cutting parts of the dies are comparatively wide. They need more effort to use than the adjustable type, and are seldom employed for pipes larger than 2 in. diameter. The adjustable stock die (Fig. 1, page 933) has narrow chaser dies, requiring less effort for cutting the thread. The dies slide in and out of the body of the stock, their position being controlled by a scroll plate operated by a lever. According to the position of the lever the dies can be set for use on a given size of pipe. These stocks may be obtained with ratchet handles for use where space is limited. Geared-down ratchet handles are also used with the very large sizes, to reduce the effort required to operate the stock. There are many makes of stocks and dies on the market, and the manufacturers' instructions should be followed in using these somewhat delicate tools.

Whatever the type of stock, there will be marks on it corresponding to various size pipes. The dies should be set accurately to the proper size although, if it is found that this leads to too tight or too loose a thread, adjustments may be made. In applying the dies to the pipe it is vital that the face be at right angles to the pipe. This should be ensured by the proper use of guides. If this is not attended to, a crooked thread will result and the pipe will not line up with the fitting into which it is screwed. After the first two or three revolutions the dies will hold themselves in the proper position and they need only be turned gently and evenly. Machine oil should be applied from time to time to ease the labour and keep the dies cool and in good condition. When a sufficient length of thread has been cut the stock and dies are run back over the pipe. The pipe should be tapped to knock off any chips. A fitting should be screwed on to judge the correctness of the thread. If it is a little tight the thread may be gone over again with the dies set a little closer.

Jointing. The pipe thread and the female thread inside the fitting should be coated lightly with a thin liquid mixture of boiled linseed oil and red and white lead. Alternatively, one of the patent jointing compounds may be used. The male thread should now have a few strands of hemp wrapped round it in the same direction as the thread. The fitting may then be screwed on, care being taken to use just sufficient force to make a tight joint without splitting the fitting.

In boiler houses and calorifier rooms flanged fittings made of cast-iron with integral flanges cast on each outlet may be used. The flanges are drilled for bolts to take mating flanges. A typical flange T is given in Fig. 5. The drilling is in accordance with B.S.S., the most usual being Table II. This applies to water



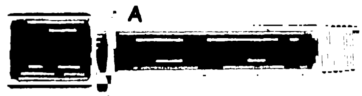
PIPE : IRON AND STEEL. Fig. 5. Typical flanged T for jointing, the flanges being drilled for bolts.

Table II. Flanges for Pipes, Valves, and Fittings
For Working Steam Pressures up to 50 lb. per sq. in.

Nominal pipe size	Actual outside diameter of pipe	Outside diameter of flange	Diameter of bolt circle	Number of bolts	Diameter of bolts	Thickness of flange
Ins.	Ins.	Ins.	Ins.		Ins.	Ins.
$\frac{1}{2}$	$\frac{27}{32}$	$3\frac{3}{4}$	$2\frac{5}{8}$	4	$\frac{1}{2}$	$\frac{3}{16}$
$\frac{3}{4}$	$1\frac{1}{16}$	4	$2\frac{7}{8}$	4	$\frac{1}{2}$	$\frac{3}{16}$
1	$1\frac{11}{32}$	$4\frac{1}{2}$	$3\frac{1}{4}$	4	$\frac{1}{2}$	$\frac{3}{16}$
$1\frac{1}{4}$	$1\frac{11}{16}$	$4\frac{3}{4}$	$3\frac{7}{16}$	4	$\frac{1}{2}$	$\frac{1}{4}$
$1\frac{1}{2}$	$1\frac{29}{32}$	$5\frac{1}{4}$	$3\frac{7}{8}$	4	$\frac{1}{2}$	$\frac{1}{4}$
2	$2\frac{3}{8}$	6	$4\frac{1}{2}$	4	$\frac{5}{8}$	$\frac{5}{16}$
$2\frac{1}{2}$	3	$6\frac{1}{2}$	5	4	$\frac{5}{8}$	$\frac{5}{16}$
3	$3\frac{1}{2}$	$7\frac{1}{4}$	$5\frac{3}{4}$	4	$\frac{5}{8}$	$\frac{3}{8}$
$3\frac{1}{2}$	4	8	$6\frac{1}{2}$	4	$\frac{5}{8}$	$\frac{3}{8}$
4	$4\frac{1}{2}$	$8\frac{1}{2}$	7	4	$\frac{5}{8}$	$\frac{3}{8}$
$4\frac{1}{2}$	5	9	$7\frac{1}{2}$	8	$\frac{5}{8}$	$\frac{7}{16}$
5	$5\frac{1}{2}$	10	$8\frac{1}{4}$	8	$\frac{5}{8}$	$\frac{1}{2}$
6	$6\frac{1}{2}$	11	$9\frac{1}{4}$	8	$\frac{5}{8}$	$\frac{1}{2}$

From B.S. No. 10 (*Part* 2, 1926).

pressures up to 130 lb. per sq. in, and steam pressures up to 50 lb. per sq. in., meeting most requirements. When using these fittings the pipes must have flanges screwed or welded on their ends. The flanges may be of cast or malleable iron or of steel. The surfaces which meet are faced, but a jointing ring between them is necessary. The usual ring is made of corrugated brass. It is referred to as a "Taylor's" ring and is of such diameter as to fit inside the flange bolts. Before use the corrugations should be filled with jointing paste. For hot water, rubber rings are sometimes used; and for steam, rings of graphited asbestos. Both these rings are usually the full diameter of the flanges, with holes for bolts.



PIPE : IRON AND STEEL. Fig. 6. Means of disconnecting piping: A, connector and backnut; B, union, shown in part section

Connectors and Unions. Flanged joints have the advantage that when the bolts are undone a length of pipe or a fitting may be readily removed. When screwed joints are employed this is impossible, and means must be allowed for disconnecting piping if necessary after it is erected. Connectors and backnuts, or unions are used for this purpose (*see* Fig. 6). These will also be necessary where connexions are made between two fixed points. When the connector is employed the socket and backnut are run back on the long thread. The joint at the other end of the connector is now made, and then the socket is screwed forward and the joint made with hemp and paste on the adjoining pipe. A grummet of hemp is wrapped round the end of the socket adjacent to the backnut, and the latter screwed forward on to it.

When using a union the two halves are screwed on to adjacent pieces of pipe and the nut used to draw them together. These fittings should be employed every 40 ft. to 50 ft. on mains. They are also necessary at the bottoms of risers, and on every other floor for drop pipes and risers. Used thus it will be possible to disconnect the piping in reasonable sections. A screwed joint is often stubborn to move after a year or two, but if it is heated with a blowlamp and banged with a hammer it should be possible to move it.

D. FITTING AND FIXING

Piping must be adequately supported. A good allowance is a bracket every 8 ft. for ½ in. pipe, and every 12 ft. for 4 in. pipe; other sizes have spacings according to their diameter. Various types of clip are shown in Fig. 7. The "School Board" clip is used for pipes adjacent to walls, and the skirting clip for pipes fixed to wood skirtings. The pipe rings are used for pipes suspended from overhead. Where pipes come one over the other, double and single rings are used, coupled together with a short piece of pipe. If the fixing

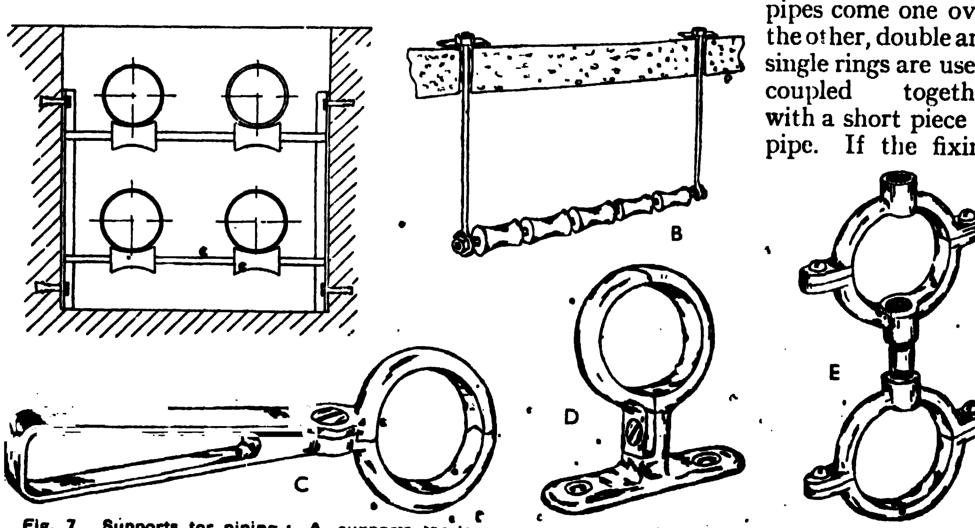
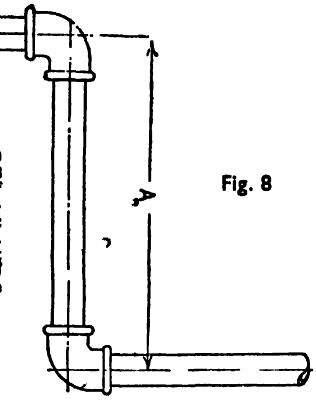


Fig. 7. Supports for piping: A, supports for large pipes in ducts, showing angles or channels at each side; B, hanger for five parallel suspended pipes; C, "School Board" clip, consisting of ring and shank; the latter is built into adjacent wall; D, skirting clip; E, coupled rings for pipes suspended one over another: (top) double ring; a barrel nipple is placed between upper and lower rings; (bottom) single ring.



PIPE: IRON AND STEEL. Figs. 8 and 9. Methods of allowing for expansion and contraction: (8) offset in pipe—A varies from about 3 ft. to 10 ft.; (9) horseshoe bend made of copper.

is to concrete, a piece of pipe with a ragged end is screwed into the upper ring. For fixing to wood, plates may be obtained with screw holes which are coupled to the rings with pipe. Where a number of pipes run side by side and are suspended from overhead, the purpose-made hanger shown is suitable. The suspension rods would normally be ⅝-in. round mild steel. The horizontal rod will be governed in diameter by the holes through the rollers shown. In the pipe ducts carrying a number of pipes special supports are often necessary. One type suitable for large pipes is illustrated in Fig. 7, A.

When long straight lengths of hot water or steam pipe are fixed provision must be made for expansion and contraction which takes place on heating and cooling. The alteration in length will amount to 1 in. per 100 ft. for hot water pipes, and more for steam pipes. A method often used to allow for this is to offset the pipes as shown in Fig. 8. The length of the offset A should vary from about 3 ft. for ½-in. pipe to about 10 ft. for 4-in. pipe. If the pipe must run in continuous line the horseshoe bend shown in Fig. 9 may be used. One of these expansion fittings should be fixed in approximately every 100 ft. of straight pipe. In order that the expansion shall take place at the offset or bend, the pipe must be anchored between them 50 ft. on each side. A suitable type of anchor is shown in Fig. 10. For normal pipe diameters the metal should be about 5 in. wide and ½ in. thick. Note that there is a gap of about ½ in. between the two halves, so that when the bolts are tightened the

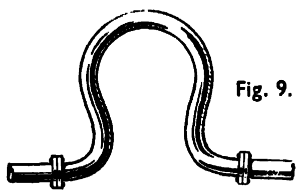


Fig. 9.

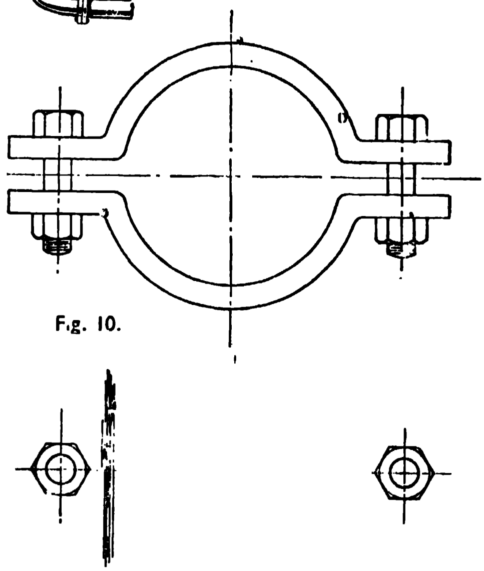


Fig. 10. Top and side views of anchor used between offsets or horseshoe bends to ensure that expansion takes place at the place provided. The gap between top and bottom halves enables the anchor to grip pipe tightly when bolts are screwed up.

pipe is securely gripped. The bolts are used also to secure the anchor firmly to the building fabric by means of brackets.

When running piping, due provision should always be made for expansion—by using one of the methods here shown.

Boiler connexions should have a swivel joint, as shown in Fig. 11, so that when the mains expand they do not strain the boiler. When risers are taken up a high building they should be offset before

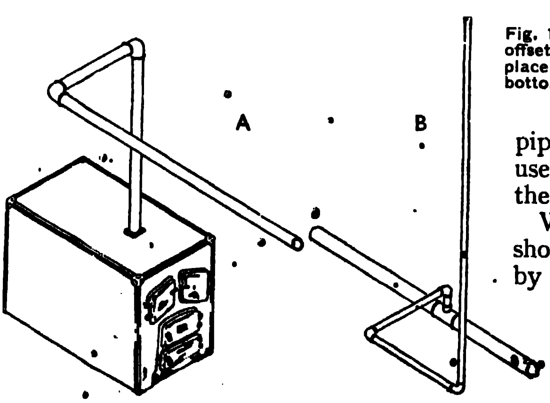


Fig. 11. Swivel joints in piping: A, connexion to boiler to avoid straining boiler when mains expand; B, same joint applied to connexion of a riser to a horizontal main.

connecting to the mains. This, too, is illustrated in Fig. 11. Also, when a building is high, radiators should not have short connexions to the risers, otherwise expansion will lift them off the floor. This will mean leaky connexions which will probably break altogether in time. It is of the utmost importance to consider this question of expansion when running piping. For hot water work the relieving of air, and for steam piping the draining of condensation must also receive attention.

PIPE AND PIPE FITTINGS: (7) MANUFACTURE IN STEEL & MALLEABLE CAST-IRON

By J. W. Cowan, A.M.I.H.V.E., A.M.Inst.W.

To conclude the series of Pipes and Pipe Fittings articles the following notes have been prepared on the manufacture of pressure-tight tubes for domestic, industrial and underground pipe lines. They do not cover steel pipes used for a variety of other purposes. See also Pipe Bending: (2) Ripple Bending; Pipework: (2) Iron, Steel and Copper.

Pressure-tight steel tubes may be either "welded" or "seamless" depending on the method of manufacture.

Welded Tubes. These have longitudinal welded seams throughout their lengths, and are intended for lighter duties than are seamless or solid-drawn tubes. The two best known of several methods of manufacture are the continuous butt weld and the lap-weld processes. Both employ open-hearth or bessemer steels of from 26 to 32 tons tensile strength, primarily because of the ease with which these may be pressure welded.

Continuous Butt Weld Process. The metal arrives at the tube mill in square-edged coiled strips of such widths as to make the desired sizes of pipes when bent to tubular formation. The process is rendered continuous by the welding of the latter end of one coil to the forward end of the next. It is upon this continuity that the great speed and low cost of the process depend.

As the first strip is uncoiled, its forward end passes into flattening rolls, and thence into a long tunnel furnace from which the still flat strip emerges at white heat. It next passes into forming rolls that bend it to the shape of a tube, and then into welding rolls of such size and shape as to set up an adequate welding pressure between the two abutting white-hot edges of the previously open lengthwise seam. Further pressure rolls consolidate the weld before the completed tube emerges from the mill in a continuous length at a rate of several feet per second.

This is cut into lengths by a travelling saw, and the still hot lengths then pass on to sizing and straightening rolls that give the tube the required outside diameter. After cooling, each separate length is tested by internal hydraulic pressure of the order of 1,000 lb. per sq. in. and mechanically hammered while under pressure.

The majority of tubes used for ordinary pipework services in sizes up to 3 in. or 4 in. nominal bore are made in this way, the only difference between one "quality" and another lying with the wall-thickness.

Lap-Weld Process. Manufacturing difficulties usually limit this method to sizes upwards of 2 in. dia. The pipes are formed from strips or plates of steel, but in this process the metal remains in straight lengths without coiling or welding together.

The first step is machine bevelling of both edges of the strip or plate so that a comparatively wide lap weld is provided when these overlap as the tube is formed. The metal is then heated to redness and, in sizes up to about 12 in. dia., drawn through a circular die. Larger pipes are made by rolling the plate to shape.

In small sizes this is followed by the first of two welding operations. In both the metal is first made white hot, and then passed over an internal mandrel, and between a pair of welding rolls. Hydraulic pressure between rolls and mandrel makes the weld, and the turning of the rolls drives the pipe forward along the mandrel bar. The second rolls-and-mandrel set is slightly smaller than the first, and serves, not only to consolidate the weld, but also to roll out and elongate the metal to a predetermined thickness. Large tubes are not elongated in this way, and a gas flame is used to heat only the overlapping edges to plasticity before the welding pressure is applied.

The completed tube is then re-heated, sized and straightened, and, after cooling, is tested hydraulically ; this may be from 3000 to 4000 lb. per sq. in. Lap-weld tubes are widely used in pipe lines, and also as structural and scaffolding members, and as mechanical rolls and rollers.

Seamless Tubes. In all processes these are forged from a solid bar of steel.

In one method, the push-bench process, a billet is heated and pierced lengthwise in a hydraulic press to the shape of a short thick-walled tube with one closed and slightly tapered end. A series of mandrels are then used to push the red-hot billet, closed end first, through a range of circular dies of progressively decreasing diameters, so that the tube is elongated backwards over the mandrel. Frequent re-heating and change of mandrel are necessary to reduce a 3 ft. long billet to a tube perhaps over 40 ft. in length.

In another, the Mannesmann process, a billet is hot-rolled to a rod of approximately the same cross-sectional area as the metal of the tube to be made. After re-heating, the rod passes between two mutually inclined rollers that rotate in the same direction, and draw the rod slowly forward between them. This action also forms a cavity at the end of the rod by drawing metal away from the centre. The conical head of a mandrel is so placed in front of the rolls as to meet this cavity and enable the rolls to draw the metal over the mandrel in the shape of a tube. The dimensions of the pipe thus formed are determined by the setting of the rolls and the size of the mandrel head.

Seamless tubes are used for high pressure pipe lines, and in multi-tubular boilers, and also in making linings of engine cylinders.

Screwed Pipe Fittings. These are normally of steel or malleable cast iron ; others of high-duty grey cast iron, bronze and gunmetal are used only for special purposes.

Steel Fittings. Mild steel fittings have for many years replaced the earlier puddled wrought iron fittings that are now used only in particularly corrosive situations. Several methods of manufacture are employed.

In small sizes, to about $1\frac{1}{4}$ in. dia. pipe size, the best fittings are machine forged from solid bars, and then drilled out and tapped internally, or screwed externally. Short billets of metal of fully the outside diameter of the fitting are first heated, and then pressed to shape between dies in a series of hydraulically powered forging operations. Tees and crosses are first upset at the centre of the billets to provide the necessary bulges for the branch outlets. After inspection, the solid forgings pass to facing, drilling and screwing machines that automatically ensure accurate alinement of the outlets.

Larger fittings, up to 4 in. dia. pipe size, are usually made from strip steel in two halves that are later welded together. Half fittings are first punched out of hot flat strip, and then pressed to shape between dies. The halves are next cleaned by tumbling about in a rotating drum, and then each pair are flash-butt welded together in an electric resistance welding machine. After the removal of the upset from the welded seams in another machine, the fittings are air tested at 100 lb. per sq. in. under water, mechanically alined and screwed, and again air tested.

Larger fittings and specials, required in lesser quantities than the smaller sizes, are usually fabricated from tube made specifically for the purpose. In the case of a tee, a hole is cut in the main piece, in much the same way as a branch joint would be prepared in a lead or copper pipe, and then a prepared branch piece is fitted over this, and the two joined together by either oxy-acetylene or electric arc welding. The outlets are next alined by mandrels in a trueing machine. The hand-made fitting is then ready for the initial air test, followed by machine tapping and/or screwing, and final air test.

Wrought Iron Fittings. These also are required in comparatively small numbers, and are usually hand forged. The profile of the complete fitting, not a half-fitting, is first punched from strip. This is then heated and hand-forged to shape, after which the overlapping edges are hammer welded together. The outlets are then trued with the aid of mandrels and die-blocks, and the fitting, after the first air test, passes to the machine shop to be alined and screwed before the final air test.

Malleable Cast Iron Fittings. These are of two kinds, whiteheart and blackheart. For details of manufacture and annealing of the castings *see* Iron, pages 615–616. The fittings are discussed in page 767.

In both processes the distortion and misalinement arising from annealing are

then corrected, and the fittings are screwed and then air tested at 100 lb. per sq. in. under water.

This method of manufacture enables pitcher and sweep fittings, not usually available in steel, to be made as easily as the square patterns. Malleable fittings are less strong than steel ones, the normal working pressure limits being 200 lb. for water, and 150 lb. for steam and air. Further, a malleable bend cannot be altered by heating, nor may these metals be fusion welded, although, with care, bronze-welding is permissible.

PIPE BENDING: PRINCIPLES AND METHODS

By Percy Manser, M.R.San.I., R.P.

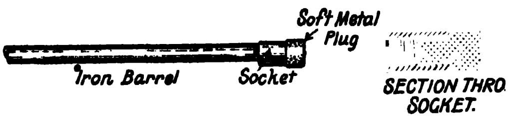
Instructor at Tottenham Polytechnic

This article deals with pipe bending by hand. For the use of bending machines see under the heading Bending Machine. The Sections are: A, Lead pipes; B, Wrought iron pipes; C, Copper and brass tubes. See *also* Pipework; and the specific articles of the Pipe group.

The terms pipe and tube are used to describe any of those mentioned, but lead is usually referred to as pipe; iron as pipe, barrel or tube; steel and copper as pipe or tube and brass as tube.

A. LEAD PIPE BENDING

Lead pipe lends itself to a different type of manipulation from that of hard metal, and the method of bending



PIPE BENDING. Fig. 1. Ramrod for driving mandrel through long lengths of lead pipe. The iron barrel has a soft metal cap, to prevent damage to the mandrel.

lead varies with the diameter of the pipe. The gauge also has an important bearing on the bending process as thin-walled pipe easily buckles or flattens. In forming a bend on heavy gauge small diameter pipe there should be no difficulty, as the wall thickness prevents flattening.

The mistake most frequently made is in trying to form a fairly sharp bend in one operation. If done in stages, by forming an easy or open bend first and then gradually closing it by a series of forward and backward movements of the pipe, the radius of the bend may be reduced considerably without any flattening of the pipe.

Bends in small diameter light gauge pipe should be formed to a larger radius, to avoid flats or kinks. No special tools are required, and the pipe may be bent by using the hand or knee as a fulcrum on which to pull the pipe round.

The foregoing applies to pipe in coils, but when bends are required on pipes made or cut from a coil to standard length (*i.e.* 10 ft. or 12 ft.), or on shorter lengths, bobbins may be used to assist in forming bends on pipes of 1 in. dia. and upwards. Steel bending springs (*see* later) are also used for pipes of 1 in. to 2 in. diameter, and bending machines have been used for lead pipe.

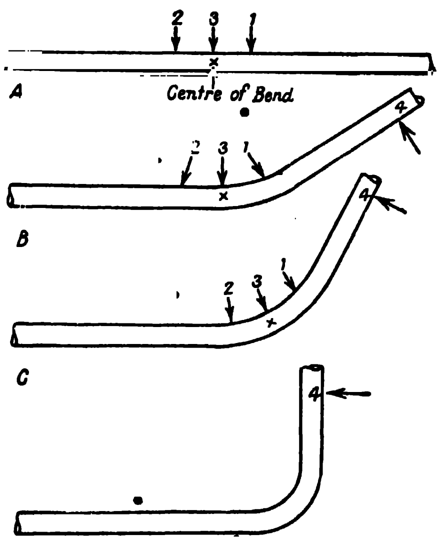
Use of Mandrel. The first thing to do is to straighten out the length of pipe on the bench and then true up the bore by passing a hardwood mandrel through the pipe, to remove any indentations. The mandrel should be greased a little with tallow, to assist its passage. For short pipes it may be driven through with a stout stick of wood and a hammer or mallet. For long lengths it can be driven well in with the stick and hammer, and completed with the aid of a ramrod of screwed iron barrel having a soft metal cap to prevent damage to the mandrel (*see* Fig. 1). As the mandrel is driven through, the pipe should be gently dressed with a softwood dresser or lead flapper to obtain an even surface without ugly marks.

The method of bending depends on the size of pipe. We will deal first with the use of bobbins for bends on pipes of 1 in. to 2 in. diameter, and assuming a square bend to a given radius is required. Set out the bend on bench or floor, or prepare a wire template of it. Mark the position of the throat of bend on the pipe and, using a softwood bending stick or dresser, slightly flatten the pipe at right angles to the throat and heel, as in Fig. 2. This should be done carefully so that the pipe takes

Fig. 2. Lead pipe flattened at right angles to throat and heel preparatory to bending.

an oval shape for a distance sufficient to form the bend. The object of this flattening is that when the pipe is bent, the oval form will tend to resume its correct circular shape without undue kinking.

The next step is to well heat the pipe along the flattened portion by using a blowlamp, gas jet, hot lead or other available means, and to apply the heat as evenly as possible so as to avoid uneven patches (which result in kinks, twists or flats during bending). The pulling round of the bend may be done by using the hand or knee as a fulcrum, utilizing a protective pad of felt or carpet against burning. The bend is formed in easy stages by pulling each side of the throat first and the centre last (Fig. 3). If the hand is used, the worker has a better



PIPE BENDING. Fig. 3. Making a bend in lead pipe : A, straight length (x indicates centre of proposed bend) ; B and C, stages during process ; D, bend completed. During bending, pressure is applied in order at points 1, 2, 3 and repeated until bend is as shown at D. The upward pull is made at 4. Any distortion or kinking can be corrected by use of bobbins. See text for further explanation

chance of "feeling" through the felt what is happening to the throat as the pulling is done.

If a kink begins to appear, open the bend slightly and, if necessary, remove kink by passing the bobbins through. If the flattening and heating have been correct the bend may be pulled up without undue kinking, and the distortion which has occurred can be put right with the bobbins. Much depends on the wall thickness of the pipe, but for pipes of 1 in. to 1½ in. diameter, an easy square bend can be pulled up in one operation as described; for 2-in. or 2½-in. pipe it is usually necessary to make the bend in

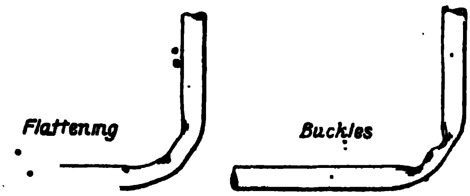


Fig. 4. Comparison of flattening and buckling. Flattening is more easily put right than buckling; both are corrected with bobbins.

stages. As with smaller pipes, it is not advisable to pull too sharp a bend in one operation. It is an easier matter to close a bend to make it sharper than to open a sharp one to make it easy.

Use of Bobbins. This is described under Bobbin, but a word here will be of help. These tools are for trueing up a bend to normal diameter and not for restoring to shape bends which have been badly buckled. When bobbins are passed through a bend having deep kinks, the heel must inevitably suffer and be reduced in thickness. The main point in bending the pipes dealt with in this section is to avoid undue buckling. Flattening, which is distinct from kinking or buckling (Fig. 4), is not quite so important, as it is more easily put right.

Knuckle Bends. These are of a very sharp type and formed near to the end of a pipe. In pulling the bends the throat must be kinked and afterwards worked out with a bent bolt and hammer, and then dressed round towards the heel of

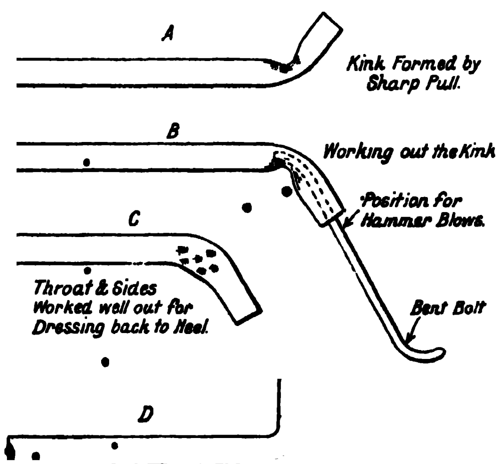
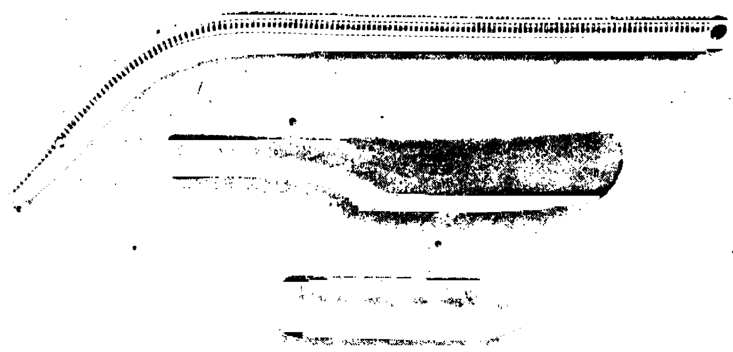


Fig. 5. Knuckle bend made with bent bolt and hammer. The steps A, B, and C are repeated until D is obtained. For bends of this type the method is superior to that illustrated by Fig. 3



PIPE BENDING (Lead.) Fig. 6. Tools for lead pipes : (top) coil spring made of square section steel, for pipes 1 in. to 2 in. diameter (see p. 775) ; (centre) bending stick or dresser ; (bottom) mandrel for trueing pipe bore (see p. 772).
Shetack Tool Works, Ltd.

the bend. The curved ends of the bent bolt should be smooth, to avoid damage to the interior of the pipe.

Many other types of sharp bends may be formed in this way when they are near enough to the end of the pipe to enable a bent bolt to be used. It is a superior method to bobbins for bends of this type, as the bolt enables the throat to be properly worked out and the surplus driven over to the heel (*see* Fig. 5, p. 773).

Bending Stick. The choice of a bending stick (Fig. 6), or dresser, varies with different people. Boxwood is considered by some to be too hard, as it leaves marks after each blow. A well-rounded hornbeam dresser is favoured by many, whilst others fashion them from a piece of suitable tough wood (a piece of a putlog is very good). As a precaution against undue marking of pipe some workers cover the body of the dresser with smooth felt or similar material.

Larger Pipes. Bends on pipes 3 in. and upwards in diameter are formed in a different manner from those on smaller pipes, as the wall thickness of large pipes used in domestic plumbing is comparatively thin ; when bent, the throat caves in or buckles, and the sides bulge (Fig. 7, A and B). The radius of the bend will determine how the pipe must be pulled round to form the bend, and the amount of buckling which should take place

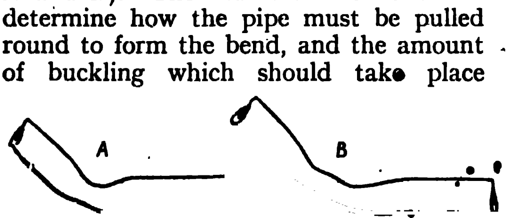
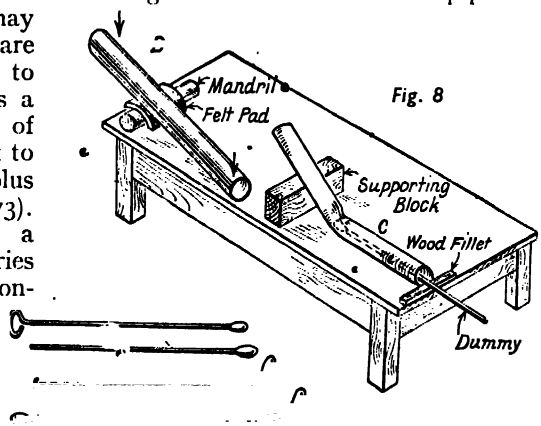


Fig. 9. Amount of buckling in (A) sharp bend, and (B) easy bend.

(*see* Fig. 9). If sharp, one pull is usually sufficient to start the bend ; but if easy, two or three may be taken, as the buckles formed need not be so acute.

The bend should first be set out or a template made. Mark the position on the pipe, apply heat evenly to the area of the bending, test for heat by squeezing a few drops of water from a wet swab and allowing them to fall on the pipe. If



E

Fig. 8. Making a bend on large-diameter lead pipe : C, throat is worked out with dummy until bend is at desired angle ; D, bending pipe over bench end ; E, types of dummy. (*See further in accompanying text.*)

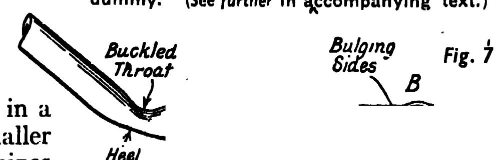


Fig. 7. Bending large-diameter lead pipe. A, throat buckles as bend is started ; B, sides bulge, and the bulges are dressed towards heel to thicken it. See Fig. 8.

the heat is right, the water will sizzle and roll about to some extent ; but if too hot it will immediately "jump" off. Lead becomes brittle at a low temperature ; the melting point is 617° F., so care should be taken not to overheat the pipe. Working it when too hot may cause a fracture, and melting can easily occur.

The pulling round of the pipe may be done by using the knee (protected by a pad) as a fulcrum, or by laying the pipe

over a padded mandrel and pushing the end downwards, as at D, Fig. 8.

If the bend is near the end of pipe, a mandrel may be inserted to obtain more leverage. The bent pipe is then laid on each side in turn and the bulged sides dressed back towards the heel, this is followed by working out the buckled throat as at C, Fig. 8. If desired the throat may be worked out before dressing back the sides, the main point being to make the surplus lead from the throat travel to make up the deficiency in the heel. After restoring the bore of the pipe to normal, another pull or pulls must be made, according to the bend required, and when complete a bobbin is passed through to true up the bore. The bobbin should pass easily; if force is required to get it round, the bend is too small and should be opened with the dummy.

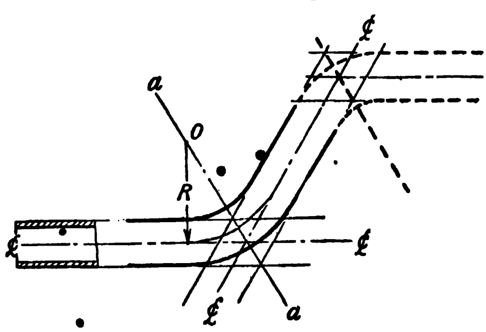
Another method of pulling round a bend is to fix a mandrel vertically through a hole in the bench and use it as a fulcrum.

When dummying out the throat (for information about dummies *see* later), the pipe should be held firmly, and to prevent it slipping towards the operator a small strip of wood should be fixed to the bench as in C, Fig. 8. For long lengths of pipe an assistant is necessary; but for short lengths use is often made of a box or block of wood to support the pipe (as at C, Fig. 8) when working single-handed. Various contraptions may be fixed up to take the place of an assistant, but pipe bending of this type is in the main a two-handed job.

Setting Out Lines for a Bend. This is not a difficult matter where bends are required in the same plane. The setting out can be done on the bench, floor or any suitable surface. Draw parallel lines equal to outside diameter of pipe and set off others at required angle of the bend, as in Fig. 10. Draw the centre line C/L and line *a a*, cutting the intersection of parallel lines. Set off at right angles to C/L the radius R of the bend, cutting *a*, *a*, in the point O. With O as centre and R as radius, draw the outline of the bend. The same rule applies to square or acute angle bends, the main difference being in the radii of them, which is based on the diameter. Thus, a bend is referred to as being of a radius equal to so many times the diameter of the pipe. Where bends on one pipe are required in different planes and to different angles they must be set out separately, or a template prepared from which to work. (*See also* Setting Out.)

Dummies. These are bulbous heads of solder fitted in various ways to handles of cane, steel or iron barrel and of lengths to suit the job in hand. When they are required of different lengths a good plan is to have the head formed on a screwed socket of iron or brass, as this may be fixed to a length of ⅜-in. or ½-in. barrel as required. Stout malacca cane handles are very good, as they impart "spring," which assists the process. Thin steel rod ⅜ in. or ½ in. diameter also forms a good handle, and the end may be looped as shown at E, Fig. 8. These steel rods may also be bent quite a lot to form a bent dummy when necessary. The dummy heads can be cast on to the rod or socket, or may be wiped on. Cane handled dummies usually have a tinned ferrule of brass or copper riveted to the cane, and the head is then wiped on with ordinary solder—not too hot. When using dummies the strokes should be short and sharp so as to get as smart a blow as possible on the throat without unduly striking the heel. The strip of wood fixed to the bench at C, Fig. 8, also acts as a fulcrum on which to work the dummy.

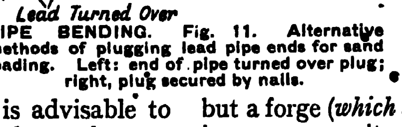
Bending Spring. This tool (Fig. 6, p. 774) is a spiral spring having a loop at one end, and enables lead pipes to be bent without distortion of the bore. The process is sometimes referred to as spring loading. The spring should be greased with tallow and pushed into the pipe so as to coincide with the position of the



PIPE BENDING. Fig. 10. Setting out bends. The dotted lines show completion of an offset or double bend. The method used and the lettering of the diagram are explained in text. *See also* Setting Out.

bend, which is then pulled round in the usual way over the knee or by using the hand as a fulcrum. The bending will

invariably cause the spring to fit tightly; to withdraw it from the pipe, a twisting or screwing movement must be applied which reduces its diameter slightly and enables it to be withdrawn. A small lever may be placed through the loop at the end to assist the twisting process. As with ordinary bending, it is advisable to heat the pipe, as it makes the work more easy.



PIPE BENDING. Fig. 11. Alternative methods of plugging lead pipe ends for sand loading. Left: end of pipe turned over plug; right, plug secured by nails.

Winch. Large diameter bends are sometimes restored to shape by the winch method, which consists of drawing through the pipe bobbins threaded on stout rope or cable attached to a winch. The bobbins are graduated in size, the leader being small and the remainder increasing in diameter up to the last one, which is equal to the bore of pipe. The bend is kept hot whilst they are passing through and forcing out in gradual stages the buckles or flats formed by the bending process.

Sand Loading. Bends of an easy radius may be made on lead pipes by filling them with sand. A tight-fitting wood plug should be driven into one end and secured by nailing or by dressing over the end of the pipe, as in Fig. 11. The pipe is then stood on end and filled with fine dry sand, which must be packed as tightly as possible. Another wood plug is driven into the top end and secured. Heat is applied evenly to the area where the bend is to be formed, and the bending is done in easy stages. If a fairly short length of pipe of small diameter, bending can be done by pulling the ends round, when the heated portion will give to form the bend; but for larger pipes pressure must be exerted on as large an area of the throat side as possible, whilst the ends are pulled round. Buckles or excessive flattening should be avoided, but the sides will no doubt bulge; these should be carefully dressed back, using a large flat-faced dresser and a felt. If buckles show signs of appearing they must be carefully dressed back from each side before proceeding to complete bend.

B. BENDING MILD STEEL PIPES

Mild steel pipes may be bent by hand or by machine. Since machine bending is dealt with in the article on Bending Machine, this section is limited to hand methods (*but see also* p. 781).

Cold bending by hand is possible only on small diameter pipes when the bends or sets are of easy radius, especially if the pipe is of steam strength; but as a rule some form of heat is necessary to obtain neat results. The heating medium varies, but a forge (*which see*) is generally used and is a necessary item where a large number of bends and sets are required on pipes of different sizes. For small jobs and repair work, where perhaps a few bends or sets are required on pipes up to 1½ in. in diameter, a plumber's furnace (*see under* Blowlamp) is a useful asset, being easily handled and transported. These furnaces are usually fitted with an asbestos-lined baffle plate which deflects the flame on to the top side of the pipe whilst it is being heated. Where an oxy-acetylene welding plant is in use the blowpipe is often employed as a heating medium for making bends, and in this connexion a multiple jet consisting of several nipples on one head was introduced a few years ago. It is sometimes necessary to spring a pipe in order to bring it into alinement with another, and this is one of many jobs where the blowpipe can be used to heat the pipe in situ and enable it to be bent and brought into line without disconnexion and removal. Care must be taken to protect roofwork, etc., from flame of blowpipe.

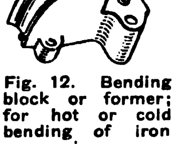


Fig. 12. Bending block or former; for hot or cold bending of iron pipes.

The next item required is a vice (*which see*), and this can be of the staple or engineer's type. Bending blocks or formers (Fig. 12) are useful for hot or cold

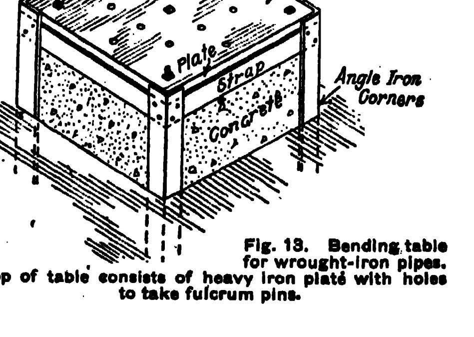
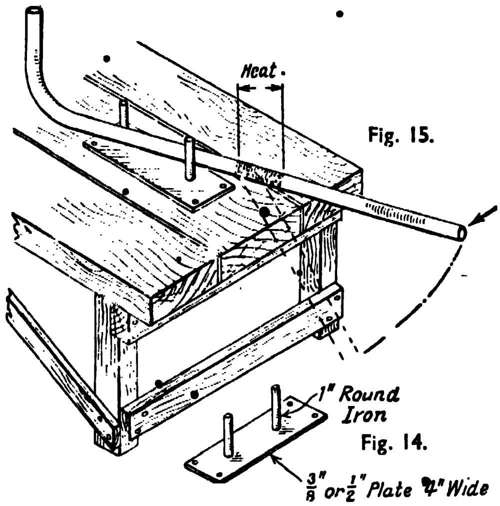


Fig. 13. Bending table for wrought-iron pipes. Top of table consists of heavy iron plate with holes to take fulcrum pins.

bending, and bench or bending-table pins are used quite a lot, especially for pipes of large diameter. The bending table consists of an iron block in which are a number of holes. Iron pins are placed into the holes in the positions required and thus act as a fulcrum on which to lever the pipe round to form the bend (*see* Fig. 13). They are suitable for use in large works for many purposes other than pipe bending.

A variation of this appliance can be made for use on any job by welding two or three pins of 1-in. round iron to a piece of $\frac{3}{8}$-in. or $\frac{1}{2}$-in. plate and fixing it to



PIPE BENDING. Fig. 14. Iron bending plate with 1-in. iron fulcrum pins. Used for bending iron pipe. Fig. 15. Showing use of bending plate illustrated in Fig. 14.

a solid bench, as Figs. 14 and 15. In using the pins care must be taken that the heated portion of pipe does not press against them, or a dent will result.

Bending Methods. The pattern should be set out as in the case of lead, or a template of the bends prepared. The position of the centre of the bend is marked in chalk and the pipe heated for a distance each side of the mark, according to the type of bend to be made. For a sharp bend the heat will be short and for an easy bend a long heat is required.

With sharp bends it may be necessary to cool the pipe if the heat is too long, as it is sometimes difficult to obtain a heat of the correct length. Whilst the heating is in progress the pipe should be turned round gradually for even heating, and must not be allowed to burn (to become more than red hot). If the bending is to be done in a vice two methods may be used:

1. The jaws of the vice must be in good condition. The pipe is gripped beyond the heat and either pulled upwards or pushed downwards in a line with the jaws. The pull is sustained until the sides of the bend show signs of bulging. It is then removed and replaced in the vice at the bend and the bulged sides squeezed back. If still hot enough this is repeated if necessary, or the pipe is further heated until the bend is complete.

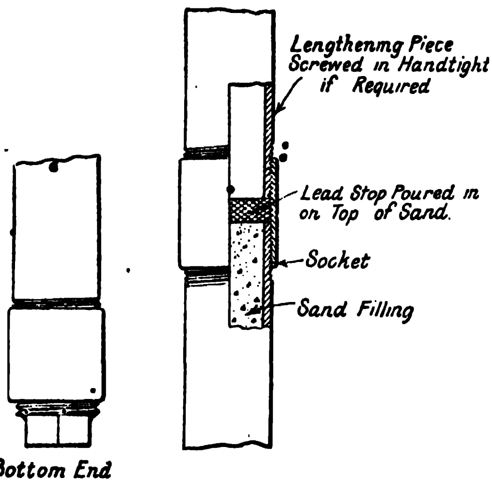
2. Gripping the pipe in the vice beyond the heat and pulling the end round at an angle with the vice. The bulging and squeezing back are carried out the same as in method 1.

Loading. For pipes which require loading, sand is a useful material and easily obtained. It should be fine and thoroughly dry before placing it in a pipe; if damp the subsequent heating of the pipe will cause steam to generate with possibly dangerous results. One end of pipe is plugged and the pipe is stood up on that end. Sand is poured in at the top end, and to ensure tight packing the pipe is tapped with a piece of wood whilst filling is in progress. The top end is then tightly plugged. The position of the bend is marked, the pipe made red hot as required, and the bend formed as already described. Bulging is less likely to occur with a loaded pipe, but it is possible; if it occurs, treat as before described.

Plugging the Ends. The method used depends on whether the pipe ends are plain or threaded. If plain, well-fitting wood plugs driven well in will answer. If threaded, an ordinary socket and plug or a cap will answer for the lower end. The top end may be closed by loosely screwing on a socket (a taper socket, if possible) and then pouring in hot lead. When cool, screw up the socket tight. It may be necessary just to caulk the lead to tighten up the shrinkage. If the length is short, as it usually is in examination tests, the top socket should be an ordinary straight one and the lead filling be kept low enough for another piece of barrel to be screwed on so that the job can be handled with comfort and efficiency (*see* Fig. 16, page 778).

Position of Seam. Wherever possible the seam of iron pipe should be at the side of the bend, but, of course, this cannot be the case when two or more bends are made in different planes, as in Fig. 15.

Galvanized Barrel. When making bends on galvanized pipe the zinc coating should be removed, as soon as it melts,



PIPE BENDING. Fig. 16. Part section of wrought iron pipe, showing lead plug on top of sand loading. Lengthening piece is seen screwed on.

by means of a stiff wire brush or scraper. Failure to do this may result in the pipe fracturing at the bend as the zinc alloys with the iron and renders the pipe brittle. Pipes have been known to break in two when the zinc coating has not been removed.

C. BENDING COPPER AND BRASS TUBE

The bending of tube by machine is described under the heading Bending Machine, where typical machines are illustrated and described.

Loading the Tube. The bending of copper tube without the aid of a machine may be done in a variety of ways, according to the gauge of tube and the type of bend. In most cases it will be necessary to load the tube—*i.e.* fill it with sand, lead, pitch or rosin—although heavy gauge small bore tube can be bent to a fairly small radius without loading. Copper tube can be obtained either "hard" or "annealed," but the light gauge tube used for domestic plumbing is usually sent out half hard so that bends may be formed without difficulty.

Copper becomes tough and hardens with working, and re-annealing is often necessary when making bends by hand.

If the tubing is hard it should be annealed before attempting to bend it. Annealing consists of heating it to a cherry red, and then allowing it to cool gradually, or cooling by quenching in clean cold water.

Filling. The main point is to make sure this is compact, for if incomplete (containing "fissures" or "breaks") trouble will arise as soon as bending is commenced. This is especially the case with lead, pitch or rosin, although sand filling will cause trouble if not properly packed.

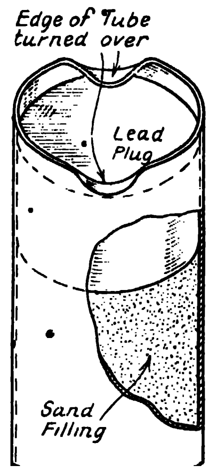


Fig. 17. Plugging end of sand loaded copper tube.

Sand. Should be fine, clean and dry. Wood plugs may be used to confine the sand in the tube, but lead plugs are more effective. Cast a short plug in a piece of the tube to be bent, push the plug into the end of tube and secure it by closing over the tube end with a straight- or cross-paned hammer in two or three places, according to size of tube; stand tube on end, fill with sand to within an inch or two of top, pour in hot lead to form another plug and secure as described. The method is shown in Fig. 17. A useful outfit for bending sand-loaded tubes is the "Enpee" sand compressor (Fig. 18). This is designed to avoid filling the whole length of tube. Sufficient sand to form the bend is held in position between steel disks attached to rods in turn secured to the tube ends.

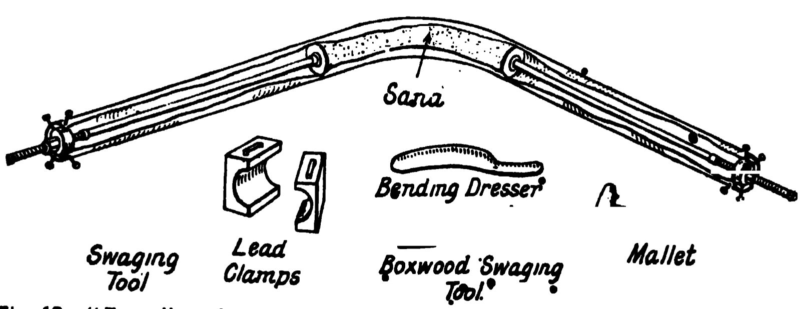
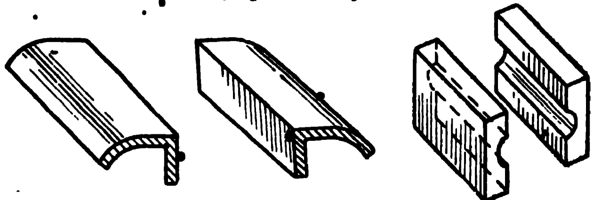


Fig. 18. "Enpee" sand compressor for bending light gauge copper tubes. The compressor, having 2-in. diam. holder or spindle, is used for pipes 2 in. to 3½ in. in diameter. Larger diam. pipes can be bent if larger holder is substituted. See text.

T. E. Freeman.

As the bending is in progress the sand is compressed by operating screw threads on the rods, which impart pressure to the disks and avoid any possibility of a loose



PIPE BENDING. Fig. 19. Lead vice clams for hand bending loaded copper tubes.

condition in the sand filling. This is shown by Fig. 18 in the opposite page.

Lead Filling. Can be done by first plugging one end of tube with wood; or standing the tube in about an inch of sand; or plugging the end with a wad of cloth or brown paper. The tube should be well warmed and lead poured in very hot (not red hot) in as continuous a stream as possible. If a pause is made in the pouring, keep the lead at top in a molten condition so that the next pouring will unite to form a solid mass from end to end.

Pockets or butts must be avoided. It will greatly assist if heat is applied to the tube during the filling process. Lead-loaded tubes can be bent almost immediately filling is complete if desired, but the hands must be protected against burns. Lead-filled pipes should be annealed beforehand, but heat may be applied during bending (not sufficient to melt the lead).

Pitch and Rosin. Poured in a similar manner to lead, but as a rule a funnel is used to assist in the pouring. Obviously such pipes must be annealed beforehand, and after filling must cool and "set" before bending is commenced.

When removing lead, pitch and rosin filling, the heating should be commenced at the end of pipe; when melting occurs apply the heat gradually along the pipe or bend in such a way that the filling does not suddenly issue like a rod, or the operator may get injured by splashes of hot material.

The removal of sand filling needs no description, but in all types of loading care must be taken to see that the interiors of pipes are well cleaned after they have been emptied, and all traces of the filling medium removed.

Spring Loading. This is suitable for pipes up to 2 in. dia. and consists of inserting a steel spring in a similar manner to that described for lead pipes (*see* Section A). The tube should be annealed along the distance required for the bend before inserting the spring. These springs are provided with handles fitted with a left-hand screw, which can be replaced with an iron eyelet so that a rod can be attached for passing the spring into a length of pipe to form a bend near the centre. By turning the rod (to impart a screwing motion) the spring is reduced slightly in diameter and can thus be withdrawn.

Hand Bending of Loaded Tubes. This may be achieved in various ways. The chief point to remember is that copper (although classed in plumbers' work as a "hard metal") is easily damaged and must be protected during the bending process. Lead vice clams, plain and shaped to fit the pipes (*see* Fig. 19), lead sheathed bending eyes and collars should be used; and when necessary sheet lead "pads" placed between the tube and iron levers, fulcrums, etc. Spring-loaded tubes may be bent round the knee, or one end held in a vice clamp, or pulled round on a circular wooden former.

Lead-loaded tubes can be treated similarly, or bent in a wood block as Fig. 20. The bending block (*see* Fig. 12) is a useful asset, but the pipe must be protected from being damaged by the eye bolt. A thick pad of lead should be placed in between, but if a large eye bolt is fitted a radiused block of lead or hardwood can be inserted.

A simple but inexpensive and useful outfit for forming bends is shown in Fig. 21. A few circular pieces of wood, preferably hardwood, and an eye bolt sheathed with lead will enable bends of different radius to be made without difficulty on pipes up to $1\frac{1}{2}$ in. diameter. One or two formers

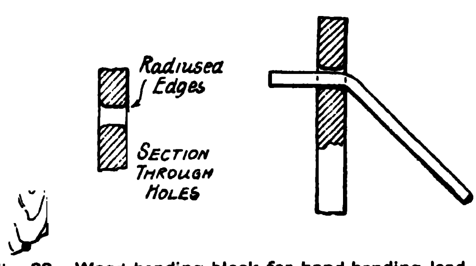


Fig. 20. Wood bending block for hand bending lead-loaded copper tubes.

(as shown at G) may be made if desired from " hards," and will be found useful for bends of small radius. The wood blocks can be hollowed to resemble a former, but it is not absolutely necessary. If tube is to be bent whilst hot they can be sheathed with sheet copper to prevent scorching, and the bench can be protected with a sheet of iron or asbestos. Owing to the softness of copper there is a tendency for it to bend, as shown by dotted lines at A, due to the leverage. To prevent this a length of iron barrel should be slipped over the tube and as close up to block as possible. The inside edge of the barrel should be filed down and a piece of sheet lead inserted to prevent damage to the copper tube, as at B. The use of the iron barrel is also necessary when the copper is short and leverage is required.

As sand-loaded tubes can be made red hot they are best bent by securing them in vice clamps and, after heating at the point of the bend, pulling round

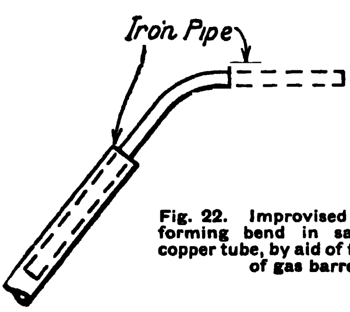
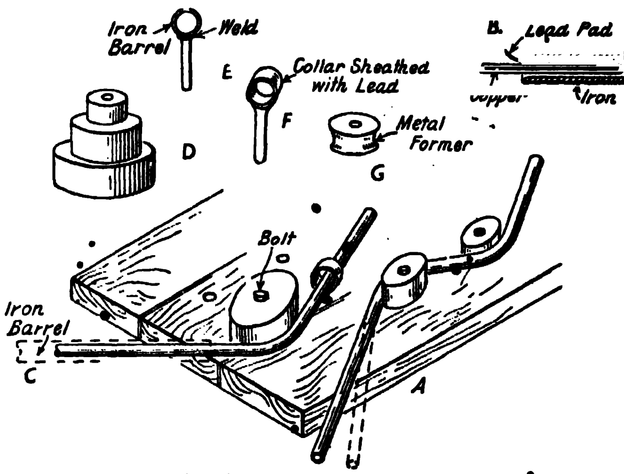


Fig. 22. Improvised method of forming bend in sand-loaded copper tube, by aid of two lengths of gas barrel.

in a horizontal direction in gradual stages.

In all hand bending operations much depends on the size of tube, type of filling, nature of bend and the tools and equipment available. If a large amount of bending is to be carried out, special apparatus can be made up; but improvised methods often have to be adopted where only one or two bends are required—such as that shown in Fig. 22, in which bends of 45 deg. were made in three pieces of 1½-in. tube. The tubes were loaded with builder's sand, and the bends formed with the aid of two pieces of gas barrel. Heat was applied by means of an ordinary blowlamp.



PIPE BENDING. Fig. 21. Outfit for copper tube bending, showing lead or hardwood formers on bench. To prevent the tube bending in wrong direction, as shown by dotted lines at (A), an iron barrel is slipped over the tube (C) after a lead pad (B) has first been inserted. Wood or lead formers (D) may be used for bends of small radius. E, F, collars ; G, metal former.

Rippling. In the hand bending of copper tube, it is found that ripples often appear in the throats of bends. These must not be allowed to become too pronounced, or difficulty will be experienced in removing them. If they happen to be rather too deep the bend should be opened a little before working them back.

Hardwood mallets, rounded dressers, ball- and flat-faced planishing hammers and swages are used for the purpose. The ripples are gradually worked back towards the sides or throat as found necessary.

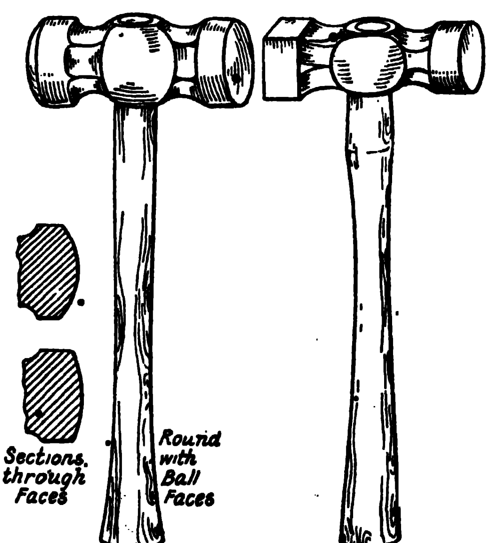


Fig. 23. Planishing hammers for removing ripples in copper tubes.

Final cleaning up is done with the hammers mentioned (Fig. 23), which have smooth, highly polished faces; and by draw filing, rubbing with emery cloth and, if required, buffing with tripoli paste and polishing. The buffing and polishing is not usually akin to the plumber's job, being more within the province of the coppersmith or the brass finisher.

Brass Tubing. This is not used in plumbing work to the same extent as copper. It is of two kinds, solid drawn (seamless) and brazed seam. The small-diameter tube, as used for gas fires, etc., is usually solid drawn and supplied ready annealed, so that bends or sets may easily be made. In many instances it is also polished or plated. Hard tube must be annealed for bending.

Brass is an alloy of copper and zinc and needs careful heating; at black heat it becomes brittle, and if overheated will "burn" and destroy the zinc content. A faint red heat is sufficient for annealing, and cooling must be gradual; sudden cooling by quenching with cold water renders the metal hard and brittle. When annealing brazed tubing, overheating must be avoided, or the brazing material may be melted. Small diameter tubes can be bent unloaded to medium radii by manipulation with the hands; or if preferred, by the use of a wood bending block similar to Fig. 20; but if sharp bends are required the tubes should be loaded. Pitch or rosin are good loading materials for either small or large tubes, and bending may be achieved by the methods described for copper tubes (with the exception that brass is bent cold).

PIPE BENDING: RIPPLE PIPE BENDING OF STEEL PIPES

By J. W. Cowan, A.M.I.H.V.E., A.M.Inst.W.

The ripple bending of steel pipes of 3 in. dia. and upwards has much to commend it, both as shop and site practice. The advantages of this method are:

(1) The total avoidance of heel-stretch by the taking-up of the whole of the heel-throat difference in length in ripples formed in the throat of the bend.

(2) The ease and speed with which comparatively large unloaded pipes may be bent accurately with an easily-made bending frame, a chain block, and a welding blowpipe, without the heavy equipment of other methods.

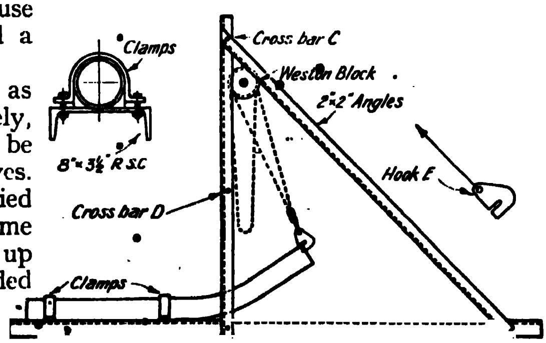
(3) The unusual flexibility of such bends due to the unstretched heel, and the rippled throat. These provide a measure of "spring" and "give" under expansive movement often absent from smooth bends whether forge or machine made, because of a thinned and tautened heel, and a thickened and unyielding throat.

These bends, sometimes known as creased bends, and also, but inaccurately, as corrugated and wrinkled bends, can be made in a variety of single and double curves.

Factory methods are not easily applied at site, but a simple bending frame (Fig. 1) should be sufficient for pipes up to 9 in. dia. The frame may be of welded construction for greater rigidity, but a bolted assembly, admitting of easy dismantling and transport is preferable.

The frame in Figs 5 and 6 is designed for pipes up to 6 in. dia., and is built as follows.

A 10 ft. length of 8 in. $\times 3\frac{1}{2}$ in. rolled steel channel is slotted through the web about 4 ft. from one end to pass one flange of each of the two 6 ft. high 2 in. $\times$ 2 in. $\times \frac{1}{4}$ in. angle uprights. The angle flanges pass down the insides of the channel flanges, and are bolted through as seen in Fig. 6. The sloping struts, also of 2 in. $\times$ 2 in. $\times \frac{1}{4}$ in. angle, are bolted to the uprights, and also pass the inner flanges through the channel web, but without bolting as the struts are in compression in use. The heads of the uprights are spanned by a $\frac{7}{8}$ in. dia. bolt, crossbar C, Fig. 1, fitted with a sleeve of 1 in. dia. steel pipe to provide a swinging attachment for the 1-ton chain block used for bending. The clamps should be heavy,



PIPE BENDING, RIPPLE. Fig. 1. Diagram showing construction of frame for ripple bending of steel pipes. See also Fig. 5.

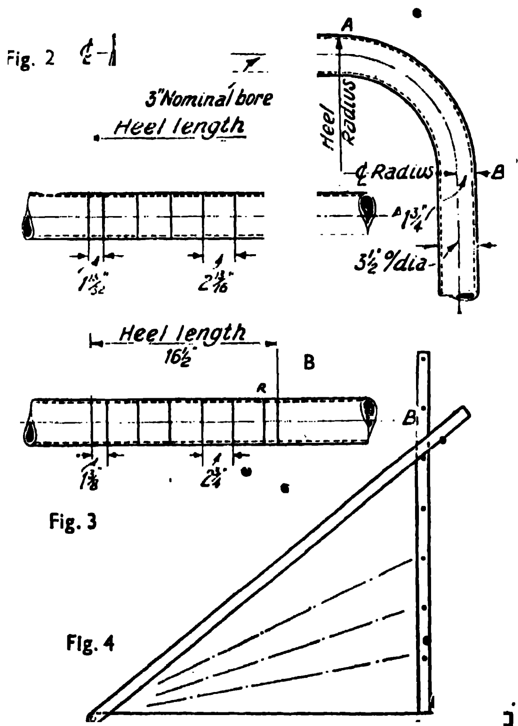
at least 3 in. $\times \frac{3}{8}$ in., and of welded construction to ensure close fitting, but not be deep enough to bear on the channel web.

A heavier frame would be necessary for larger pipes. The channel should be about 3 in. wider than the outside diameter for ease of clamping, say 12 in. wide channel for 9 in. dia. pipe. The angles also would be correspondingly stronger, perhaps $2\frac{1}{2}$ in. $\times 2\frac{1}{2}$ in. $\times \frac{5}{16}$ in. or $\frac{3}{8}$ in.

First, decide the number and the positions of the ripples, and mark these on the pipe. The normal turn per ripple is from 10° to 15°; only in the case of an easy bend of a few well-spaced ripples in a small pipe would it be prudent to exceed 15°.

The positions and spacing of the ripples are governed by the size of the bend, *i.e.* by the centre-line radius, and the length of the heel.

Assuming a 3-in. dia. $\times 90° \times 3d \times 6$-ripple bend, and referring to Fig. 2, it will be seen that the centre-line radius is 9 in. ($3d = 3 \times 3$ in. dia. $= 9$ in.), and that the heel radius is $10\frac{3}{4}$ in. (9 in. $+ 1\frac{3}{4}$ in. $= 10\frac{3}{4}$ in.). From the known properties of the circle it follows that the length of the curved heel AB will be 1.57 times the length of the heel radius. It is within this heel length of 16.8775 in. ($10\frac{3}{4} \times 1.57$) that the ripples are marked as in Fig. 3. The spacing is calculated by dividing the heel length by the number of ripples, thus, 16.8775 in. $\div 6 = 2.81$ in., say $2\frac{13}{16}$ in.



PIPE BENDING, RIPPLE. Fig. 2. A 90° bend showing centre-line and heel radii. Fig 3. Layout of ripple marks within heel length. Fig. 4. Angle gauge for use with ripple bending frame shown in Fig. 1.

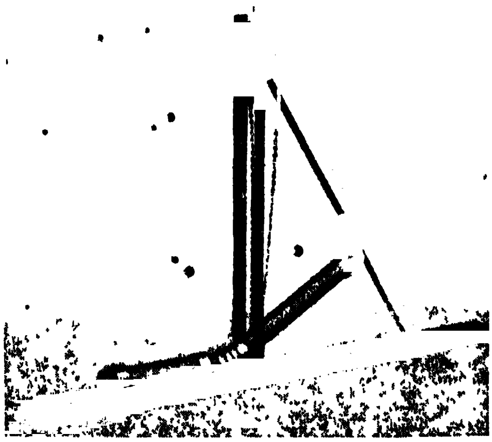
The accuracy of diagram A would seldom be necessary, and the approximations of diagram B would normally be sufficient. Ripple centres should not be closer than 2 in. because of the concentration of heat, and the likelihood of the metal between two ripples sinking into the bore during bending. The seam of a welded pipe should be kept clear of the rippling.

After marking, the pipe is clamped into the frame with marks uppermost, the first within 6 in. of the nearer clamp, and the lifting hook of the chain block (or, preferably, a hook plate as at E in Fig. 1) is attached to the free end of the pipe, and the slack of the chain taken up.

Apply heat to the first ripple mark by a neutral oxy-acetylene welding flame. A tip that burns fully 50 cub. ft. of acetylene/hr. should be used for a ¼ in. thick pipe wall, twice that required for welding, but a smaller tip may be used at first, and the size increased with practice. Heat is applied to two-thirds of the pipe circumference, and it is important that this be confined to a narrow band about 1 in. wide having the ripple mark as its centre-line. When a cherry-redness in this band extends fully half-way round the pipe the blowpipe is temporarily removed, and bending commenced by an assistant pulling on the running loop of the chain. This should produce a slight upward bulge centred on the ripple mark. When this is seen, further heat is applied, not now to the top of the ripple, but to the pipe wall on both sides of the rising bulge.

It is important after the first heating to confine the flame to the roots of the ripple, to avoid closure and flattening, and to ensure that the red-hot metal rising from the pipe wall will carry the black-hot first bulge upwards in an easy-flowing sweep of metal.

Bending is continued by either alternate or, with practice, simultaneous heating and bending till the required degree of turn has been made. This should be checked as bending proceeds, by placing a carefully set hinged steel rule, or an angle gauge as Fig. 4, between the channel and the rising pipe.



PIPE BENDING, RIPPLE. Fig. 5. A bend of 30° on a 4 in. diameter steel pipe in the frame shown in Fig. 1, page 781. Fig. 6 (right). A close up view of the bend clearly showing the ripples.
Photo, J. W. Cowan

On completion of one ripple a file and/or a scratch brush should be used to remove the black scale of the heating before commencing the next ripple. Bending is then continued ripple by ripple as in Figs. 5 and 6.

It is difficult to bend beyond 45° with the lifting chain running directly from block to pipe-end. For closer angles it is usual to pass the chain round a second bolt between the uprights, and to take it from there to the pipe-end. This, shown as crossbar D in Fig. 1, is seen at the top of the photograph (Fig. 5), in which the angle of the bend has not yet justified its use.

PIPE-COIL HEATER. Coils of piping through which steam or hot water is passed have been much used for warming air, which is blown or drawn over them by a fan. The coils are enclosed in a sheet metal casing and arranged so that air passing through the heater chamber is baffled and brought into contact with the hot pipes.

The term "coil" now scarcely applies to the modern air heater, which is built up in sections as batteries of gilled pipes ranged between steam or flow headers, and condense or return headers. This gives a higher uniform temperature in the pipes than would be the case if long coils of piping were used, when the temperature of the steam or water towards the end of the coil would be almost useless.

The finned or gilled tube batteries are used in air heaters for plenum systems of heating and ventilating, in systems of air conditioning, and also in the various types of unit heaters and air conditioning units.

Gilled tubes for air heaters are usually made of 1-in. diameter tubing, with plain, tapered, or crimped gills. They are made in copper or mild steel. Sometimes the tubes are formed oval in shape so that air flow will not be restricted and the greatest possible surface will be in contact.

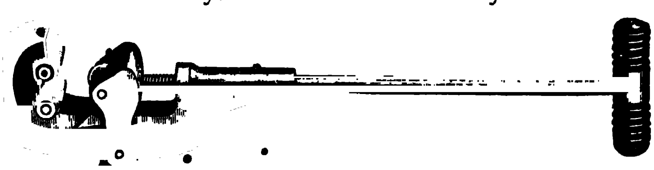
When air is passing at 1,000 feet per minute through a heater thus constructed the heat transmission is about three times that of a battery placed in ordinary still air.—*Louis J. Overton, M.I.H.V.E.*

See Air Conditioning; Ventilation.

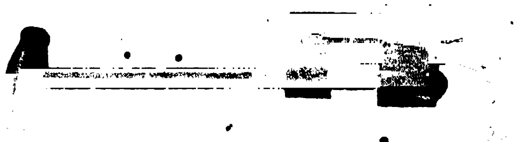
PIPE CUTTER. Cutters are used for all sizes of cast-iron, mild steel and wrought iron pipes. The majority are of the wheel type and may be single-wheel or multi-wheel, depending chiefly upon pipe size. Another type removes a strip of metal in the same way as a lathe parting-tool; and a third pattern (for steel pipes only) employs oxy-acetylene cutting equipment.

The single-wheel cutter (Fig. 1) has two broad rollers in the head which assist alinement of the hardened and tempered tool-steel cutting wheel, and also roll down the burr which would otherwise be thrown up on the outside of the pipe. This very useful tool is limited to positions where the cutter can be turned completely round the pipe—as at a bench.

Where that is impossible, a three-wheel cutter as shown in Fig 2. would be necessary. As cuts are made by each of the



PIPE CUTTER. Fig 1. Single-wheel pipe cutter; use limited to positions where cutter can be turned completely round pipe. It has rollers to assist alinement of cutting wheel.
Walworth, Ltd.



PIPE CUTTER. Fig. 2. " Barnes " pattern 3-wheel pipe cutter suitable for positions where cutter cannot be turned completely round pipe.
Ideal Boilers and Radiators, Ltd.

three wheels, this tool need only be turned through one-third of a complete revolution to make a complete cut.

Action and Use. The action of the usual wheel cutter is that of shearing rather than cutting, and it is necessary to oil the wheels, the wheel pins, and the track made by the wheels during operation, in

are also used. In view of the possibility of failure to remove this burr, experienced engineers frequently insist upon a hacksaw being used to cut small tubes. Wide-throat screwing dies are sometimes able to start over the outside burr, but solid dies almost invariably require that this also be reamered or filed off.

In an endeavour to eliminate the burrs made by smooth-edge cutting wheels, a knurled or saw-toothed wheel has been devised. The action of the rotating teeth is to cut off innumerable small pieces of metal, so that the cut is clean and square and altogether free from burrs (Fig. 3)

Fig. 4 shows another pattern of cutter

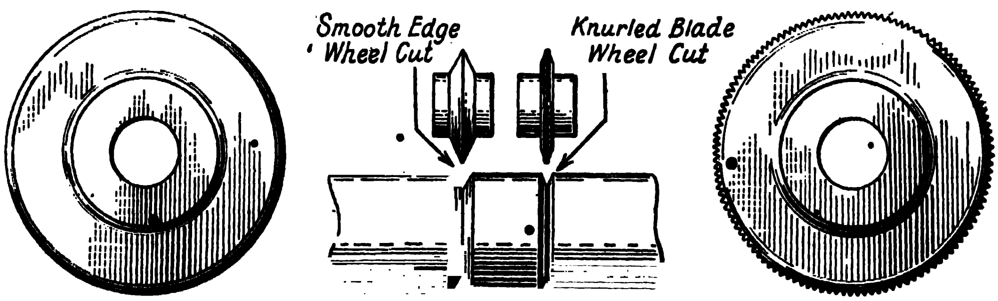


Fig. 3. Comparison of cuts made by smooth-edge and saw-tooth pipe cutter wheels.

order to prevent wear on the wheel pins and the pin sockets in the body of the cutter. Wear due to lack of oil will throw the wheels out of alinement and, with the three-wheel pattern, will cause the wheels to cut a double track and screw the

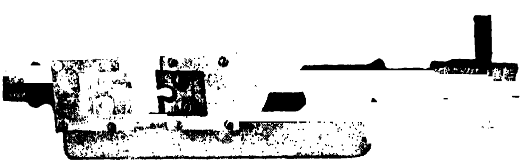


Fig. 4. " Beaver " pattern pipe cutter designed to cut steel pipes without leaving a burr. Use limited to bench work.
Ideal Boilers and Radiators, Ltd.

cutter along the pipe. Failure to oil the wheel track will cause overheating and broken or untempered and blunted wheels.

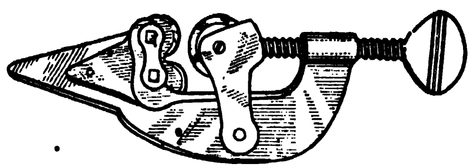
Both patterns normally leave a heavy burr inside the pipe, and the three-wheel type also throws up an outside burr. The removal of the internal burr is very important, particularly in the case of small pipes in which the bore restriction may approximate 50 per cent of the full bore of the tube. Fluted and other reamers are made for this purpose (*see* Pipe Reamer), and round and half-round files

designed to cut steel pipes without leaving a burr. The tool is self-centring and self-feeding. Springs are used to press cutters against the pipe so that they remove a narrow ribbon of metal as the tool is revolved, the action being similar to that of a lathe parting-tool. These are available in all sizes to 4 in. diameter but, like the single-wheel cutter, their application is limited to bench work.

Single-wheel cutters are used for pipes up to 2 in. diameter; the three-wheel pattern are made for pipes up to 12 in., but rarely used for sizes above 6 in.

Fig. 5. " Jones " pattern multi-wheel chain-type pipe cutter for large-diameter pipes. Especially suitable for work in confined spaces.
Jones & Attwood, Ltd

Tools for Large Pipes. Fig. 5 shows a multi-wheel cutter suitable for all sizes



PIPE CUTTER. Fig. 6. "Armstrong" pattern cutter for light gauge copper tubes. The tool is fitted with reamer for removal of internal burr.

and commonly used for pipes of upwards of 3 in. diameter. The number of wheels reduces handle movement to a minimum and makes it particularly suitable for work in confined spaces, as in trenches and pipe ducts, etc. The 6-wheel cutter illustrated is intended for 4-in. pipes. The removal of one link and wheel would reduce it to the 3-in. size, and additional links and wheels up to a total of 10 would increase its capacity to 8 in. diameter. Larger cutters of the same pattern but with longer links may have up to 14 wheels to cut pipes of 24 in. diameter.

With the exception of Fig. 4, the cutters illustrated so far have been equally suitable for steel or cast-iron pipe.

Cutter for L.G. Copper Tube. Fig. 6 shows a small single-wheel cutter designed for light gauge copper tube, and fitted with a reamer for the removal of the internal burr; the two rollers in the head prevent a burr rising on the outside. Because of the lightness of the cut, this tool may be used without a vice.

Oxy-Acetylene Cutting. Oxy-acetylene cutting blowpipes are also used to cut steel pipes and, the action being largely chemical, this method is very much quicker than any of the wholly mechanical cutting tools. Oxygen cutting-machines have been designed for work for which hand cutting would not be sufficiently accurate. Fig. 7 illustrates a portable oxy-acetylene tube cutting machine suitable for steel tubes of any wall thickness up to 2 in. It is made in several sizes for a variety of pipe diameters and is entirely hand operated. In addition to the frame and gearing, etc., it consists of a cutting head connected to cylinders of oxygen and dissolved acetylene by the two rubber tubes on the top left of the illustration. —*J. W. Cowan, A.M.I.H.V.E.*

PIPE DRILL. Used to cut a hole through the wall of a main pipe when a connexion has to be made without the use of a tee or other branch fitting.

Small connexions are normally made to underground cast-iron gas and water mains by drilling and tapping a hole through the wall of the pipe to receive the male thread of the branch pipe or ferrule, as the case may be. Cast-iron pipes designed for low pressure hot water heating work often have heavy flat "pads" or bosses cast integrally with the pipe at intervals. These are intended to be drilled and tapped as required for connexion to radiators. The pipe wall is not sufficiently thick to allow adequate depth of tapping.

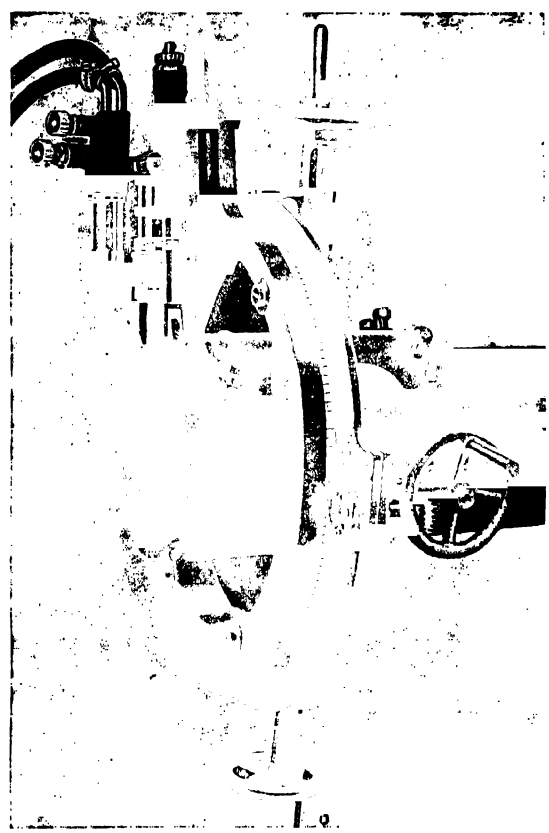


Fig. 7. Oxy-acetylene portable tube-cutting machine for steel tubes up to 2 in. wall thickness; hand operated. *British Oxygen Co., Ltd.*

Fig. 1 (p. 784) shows (*a*) an ordinary spear-head flat drill, and (*b*) a square shank twist drill, both for drilling main pipes. Instead of actual diameter size, they may be marked with the nominal bore size of pipe for which the drilled hole will be suitable.

TABLE I.—Drilling Sizes For Holes In Mains

Nominal bore of branch pipe ..	1/8	1/4	3/8	1/2	3/4	1	1¼	1½	2	in.
Size of drill to suit B.S.P. tap ..	21/64	7/16	37/64	23/32	15/16	1 5/32	1½	1 47/64	2 13/64	in.

Table 1 gives the drilling sizes of holes which have to be tapped to suit screwed mild steel or wrought-iron pipes from ⅛ in. to 2 in. diameter inclusive.

Fig. 2 illustrates a combined drill, reamer and tap, which is much to be preferred to a plain flat or twist drill. Not only does it save time, but when the hole has been drilled the drill portion of the tool acts as a guide for the reamer and tap, and ensures an easy start and a perfectly square tapping.

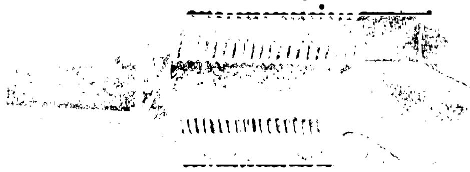


Fig. 2. Combined drill, reamer, and tap. The drill portion acts as guide to reamer and tap.
S. Tysack & Son, Ltd

PIPE DRILL. Fig. 1. Common drills for ratchet braces, used to drill main pipes: A, spear-head flat drill; B, square shank twist drill.
S. Tysack & Son, Ltd.

Small holes to suit ⅛ in. and ¼ in. pipes can be drilled by hand by the use of a breast drill (*see* Drill), but larger holes necessitate the use of a drilling pillar (Fig. 3), the base of which would fit under the main pipe, or a drilling stand, as seen in Fig. 3, p. 175 under the heading Brace. (A ratchet brace also is shown in Fig. 2 in the same page.) Behind the spring plate a pawl engages the teeth of the ratchet and enables the handle to turn the lower portion of the brace, the underside of which is provided with a square recess for receiving the head of the drill. The tool illustrated operates in only one direction (clockwise, for right-hand threads); some are made to turn in both directions and others, for heavy work, are so arranged that both strokes of the handle will turn the drill forward.

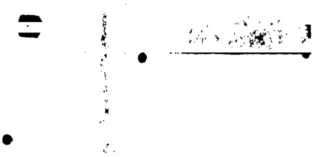


Fig. 3. Drilling pillar for large holes. The base fits under the main pipe.
S. Tysack & Son, Ltd.

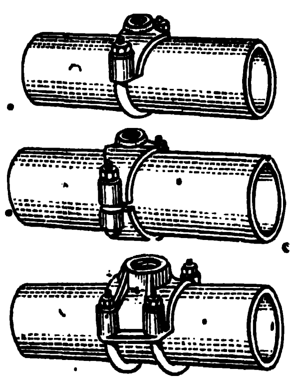
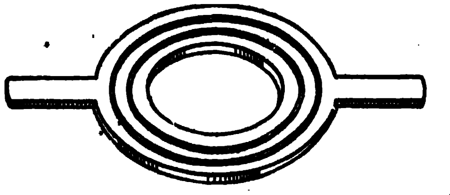


Fig. 4. Malleable iron saddles for branches from mild steel or wrought iron pipes: A and B, for gas and water mains; C, for steam pipes.
Abbott Birks & Co., Ltd.

Water Main Units. Branch connexions can now be made to water mains without need to shut down the supply. This is possible by the use of drilling units in which the operations of drilling, reamering, tapping and connecting a stopcock ferrule are done within a small watertight casing clamped to the main pipe.

Pipe Saddles. The walls of mild steel and wrought iron pipes are not usually thick enough to admit of tapping unless, perhaps, for an ⅛-in. branch connexion. For larger branches, for which a tee would be comparatively expensive (as for a ½-in. branch to a 6-in. main), a plain hole would be drilled and the connexion would be made by oxy-acetylene welding, or the use of a pipe saddle (see Fig. 4). In each case the boss is already taper-tapped for the required branch size, and the fitting need only be clamped over the previously drilled hole. Fig. 4 (*a*) is designed for gas and water mains from 1½ in. to 3 in. diameter; (*b*) for the same pipes from 4 in. to 6 in. diameter, and (*c*) is intended for steam pipes of sizes from 2 in. to 6 in. inclusive.

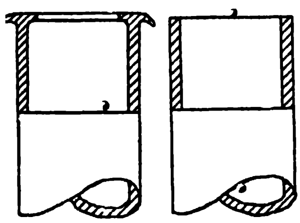


PIPE DRILL. Fig. 5. Corrugated metallic washer used to ensure sound joint between pipe and saddle.

To ensure a sound joint between pipe and saddle, a corrugated soft-metal washer consisting largely of lead (Fig. 5) is necessary. The projections are bent round the edge of the saddle during fixing and, as the joint is tightened, the corrugations sink into any irregularities of the pipe and ensure a permanently sound connexion.—*J. W. Cowan, A.M.I.H.V.E.*

See Brace; Drill.

PIPE OPENER. Tool for making a hole in a lead pipe, as for the insertion of a branch. It resembles the carpenter's gimlet, consisting of a steel boring bit the shank of which is inserted through a hardwood cross-handle and riveted over a burr. The tool is provided with a screwed nose to make entry into the pipe, but then tapers out quickly to form a hollow conical cutting portion which acts like a reamer in enlarging the entry hole. *See* Joints: (1) Wiped Joints.



PIPE REAMER. Fig. 1. Pipe ends before and after reaming: (left) burred; (right) clean-cut after use of reamers.

PIPE REAMER. Tool designed to remove either the inside or outside burr left on screwed tubes by a smooth-edge wheel-type pipe cutter, as shown in Fig. 1. The burrs are somewhat exaggerated in the diagram but, in a small diameter pipe, bore restriction frequently approaches 50 per cent. of the full bore of the tube.

Fig. 2 shows a plain triangular internal burring reamer with tempered steel blade and tommy-bar, suitable for pipes from ¾ in. to 2 in. diameter. In Fig. 3 is illustrated a spiral fluted internal reamer with tommy-bar, intended for pipes from ¼ in. to 2 in. diameter. These blades are also made with straight flutes and, as may be seen from Fig. 4, both patterns are available with square bit-pattern shanks for use with a breast brace.

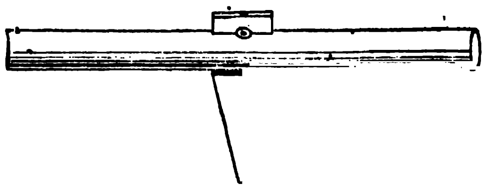
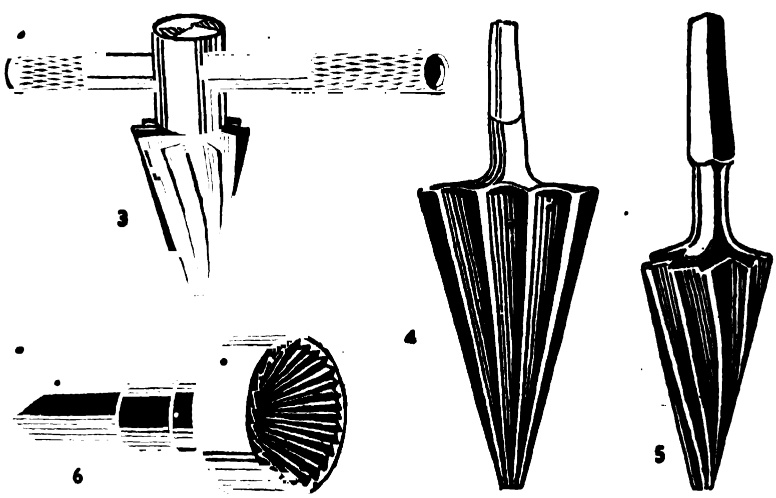


Fig. 2. "Hall" pattern plain triangular burring reamer with steel blade and tommy-bar, for pipes ¾ in. to 2 in. in diameter.
Walworth, Ltd.

The "Hall" reamer, Fig. 2, is the least costly of these tools and is less easily damaged by rough handling than the others; but for quickness and ease of working the fluted reamer in a brace is to be preferred. Hollow fluted reamers (Fig. 6) designed to remove the outside burr are also made but are not used to any great extent in Britain. They undoubtedly remove the burr better than a file, but adjustable die stocks and wide-throat screwing dies frequently enable a thread to be started without removing the outside burr.—*J. W. Cowan, A.M.I.H.V.E.*

See Pipe Cutter.



Figs. 3, 4, 5 and 6. Pipe reamers: (3) spiral-fluted internal reamer with tommy-bar, for pipes ¼ in. to 2 in. in diameter; (4), (5), internal reamers having straight and spiral flutes respectively and square-taper shanks; (6) fluted reamer for removing outside burr.

PIPE SIZING: (1) FOR HOT AND COLD WATER SUPPLY SERVICES

By W E. Fretwell, F.R.San.I., P.P.I.H.V.E., M.I.Mech.E.

Explaining the fundamental principles of pipe sizing, and giving formulae on which practical work is based, with a Chart facing p. 791. (A Chart prepared on a different basis is given under Water : (4) *facing p.* 1128.) The article is based on a paper read before the Institute of Plumbers and reprinted in the "Journal of the Institution of Heating and Ventilating Engineers." For the physical laws here referred to see Hydraulics ; Pressure ; Steam ; Water. See *also* Heating ; Hot Water Supply.

The object of this section is to endeavour to explain in simple language some of the more important physical laws controlling the flow of water through pipes and the effect of such laws on the outflow.

Pressure Head. Where water flows through pipes the energy producing motion is expressed in terms of pressure head of water or its equivalent. The pressure head is the vertical distance between the free level of water in the supply cistern and the centre of the orifice from which it flows.

Velocity of Efflux. The velocity of efflux, *i.e.* that velocity at which a fluid particle leaves the orifice of the system, can never exceed that acquired by a body falling *in vacuo* through a height equal to the pressure head.

Equation No. 1.

$$v^2 = 2gh$$

This well-known equation gives the velocity where

v = velocity in feet per second.
g = acceleration due to gravity.
h = the height in feet through which the body falls.

In order to simplify calculations the value of g is taken in this case as 32 instead of the more correct figure of 32·2 feet per second

Equation No. 2.

By taking the square root of each side of Equation No. 1 we obtain :—

$$v = \sqrt{2gh}$$
$$= \sqrt{2 \times 32 \times h}$$
$$= \sqrt{64h}$$
$$= 8\sqrt{h}$$
$$v = 8\sqrt{h}$$

Equation No. 2 gives the theoretical velocity in feet per second acquired by a falling body as eight times the square root of the height in feet through which it falls.

By transposition we obtain

$$\sqrt{h} = \frac{v}{8}$$

Squaring both sides of this equation gives

$$h = \left(\frac{v}{8}\right)^2$$

from which is obtained

Equation No. 3.

$$H_v = \frac{v^2}{64}$$

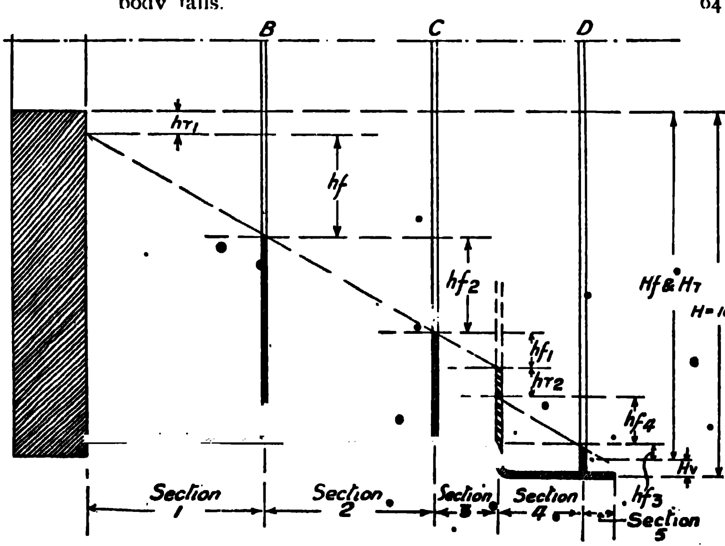
where H_v = head in feet required to produce a velocity of v feet per second.

Example. Suppose the velocity of efflux to be 8 ft. per second, according to Equation No. 3

$$H_v = \frac{v^2}{64}$$

The head H_v in feet required to produce a velocity of 8 ft. per second is therefore

$$\frac{8^2}{64} = \frac{64}{64} = 1 \text{ foot.}$$



PIPE SIZING. Fig. 1. Diagram of pipe system to illustrate flow of water through discharge pipe (for full explanation, see text).

Pressure Drop Through System. The system shown by Fig. 1 will serve to explain the conditions obtaining when water flows through the discharge pipe. The water level A in the system is presumed to remain constant. The vertical distance or head between the water level

and the centre of the outlet orifice is 10 ft.

The gauge tubes lettered B, C, and D are supposed inserted into the side of the pipe. These gauges register what is called the static head or bursting pressure on the system. Imagine water to outflow with a uniform velocity over the orifice of 8 ft. per second. The theoretical height through which a body must fall from rest to acquire a velocity of 8 ft. per second is, as already determined, 1 ft. The velocity head H_v, shown on the outlet end of the pipe is, therefore, 1 ft.

The friction head encountered by water flowing over the surface of the pipe itself is herein denoted by the symbol h_{f1}, h_{f2} etc., where the suffix $_1$, $_2$, etc., represents the appropriate section of piping. The total or sum of the friction heads is represented by the symbol H_f.

The symbol, h_{r1}, h_{r2}, etc., represents the resistance to flow of water occasioned by a sudden change in the direction of flow. The suffix $_1$, $_2$, etc., represents the appropriate change of direction.

The sum of these resistances is represented by the symbol H_r.

Equation No. 4.

$$H = H_v + H_f + H_r.$$

Equation No. 4 represents in effect a balance sheet in which H represents the capital invested and $H_v + H_f + H_r$ the expenditure. The importance of understanding this fundamental law cannot be too strongly stressed. The following explanation shows how the pressure head is consumed when water outflows from the system (Fig. 1).

1. The resistance to the flow of water entering the pipe at the cistern results in a pressure drop indicated by the head h_{r1}.

This drop in pressure is indicated by the difference in height between the surface water level A and the top of the sloping line where it joins the cistern.

2. The friction of the pipe "section 1" between the cistern and the gauge lettered B produces a pressure drop h_{f1}.

3. The friction of the pipe "section 2" between the gauges B and C produces a pressure drop h_{f2}.

4. The friction of the pipe "section 3" is indicated by h_{f3}.

5. The resistances of the two bends between the pipe sections numbered 3 and 4 is indicated by h_{r2}.

6. The friction of the pipe "section 4" is indicated by the drop in pressure h_{f4} on the gauge D.

7. The friction of the pipe between the gauge D and the end of the pipe is indicated by the pressure drop h_{f5}

8. The head required to produce the velocity of efflux is indicated by H_v.

The total pressure drop of the system shown in Fig. 1 is as follows :

(*a*) Head consumed by friction of pipes $= H_f = h_{f1} + h_{f2} + h_{f3} + h_{f4} + h_{f5}$.

(*b*) Head consumed by resistances $= H_r = h_{r1} + h_{r2}$.

(*c*) Head due to velocity of efflux $= H_v$.

Whence $H = H_v + H_f + H_r$.

In the system (Fig. 1) a head (H_v) of 1 ft. is required to produce a velocity of efflux of 8 ft. per second. The total head (H) is 10 ft. Deducting the required velocity head of 1 ft. gives 9 ft., and this represents the sum of the frictional losses of the pipes and the resistances due to sudden changes of direction, etc.

Whenever water flows through a pipe system it always conforms to the equation

$$H = H_v + H_f + H_r$$

Pipe Discharge Formulae. From what has already been said it is clear that the flow of water through pipes is controlled by physical laws and not by formulae. Pipe discharge formulae are at best an attempt to evaluate the frictional resistance to flow of water of varying temperatures and velocities of flow through pipes of different sizes and having, in most cases, an unknown frictional surface effect on the flow.

It is obvious that unless, in a pipe discharge formula, the values of certain factors are changed or new ones introduced, the calculated discharge cannot be true for smooth lead or copper pipes and for commercial mild steel screwed tubing. Apart from the relative smoothness of the pipe surface, the bore of lead and copper pipes more nearly conforms to the nominal diameter than does mild steel screwed tubing, in which the external diameter is, for a given size of tube, more or less constant for tubes of gas, water and steam qualities. In addition more fittings are usually employed on screwed mild steel tubing than for lead and copper pipes.

No two formulae for pipe discharge give the same result, and it is doubtful whether, in practice, the calculated discharge ever exactly agrees with that actually obtained.

The object of employing a pipe discharge formula should be to ensure that the pipe system is large enough to provide the desired outflow of water without employing unnecessarily large diameter pipes.

'Box' Formula. In this section the well-known formula of Thos. Box for the discharge by long pipes is employed because of its simplicity of application, and not because it is claimed that the results are more accurate than those obtained by other formulae of later date.

The formula is expressed as:

Equation 5.

$$G = \sqrt{\frac{(3d)^5 \times H}{L}}$$

Where G = gallons per minute.
d = diameter in inches.
H = head in feet.
L = length of pipe in yards.

Other derived equations are:

Equation 6.

$$H = \frac{G^2 \times L}{(3d)^5}$$

Equation 7.

$$L = \frac{(3d)^5 \times H}{G^2}$$

Equation 8.

$$d = \left(\frac{G^2 \times L}{H}\right)^{\frac{1}{5}} \div 3$$

Table No. I, (p. 789). This was calculated by the author, and is based on equation No. 5; it may be usefully employed for pipe discharge calculations. It should be noted that Box's formula, from which the table is calculated, gives the discharge from long pipes. If used for short pipes and heads of less than 1 ft. or thereabouts, the table gives results in excess of those obtained in practice.

Column 1 of Table I gives the L/H value and is obtained by dividing the length of pipe by the head. The discharge is given in gallons per minute (g.p.m.).

For a pipe 40 ft. long and a head of 5 ft., the L/H value is $40 \div 5 = 8$.

For an L/H value 8, Table I gives the discharge from a 1-in. diameter pipe as 9·5 gallons per minute.

Example 1.—Calculate the head required to discharge 36 g.p.m. from a 2-in. pipe 72 ft. long.

For a 2-in. pipe carrying 36 g.p.m. Table I gives an L/H value of 18.

Dividing the length of 72 ft. by the L/H value of 18 gives $72 \div 18 = 4$.

The required head is 4 ft.

Example 2.—Calculate the length of 1-in. dia. pipe to discharge 11 g.p.m. with a head of 5 ft.

For a discharge of 11 g.p.m. from a 1-in. pipe the table gives an L/H value of 6.

Multiplying the L/H value of 6 by the head of 5 ft. gives 30.

The length of pipe is therefore 30 ft.

General Rules for Pipes. Box's formula purports to give the discharge by long pipes in which the head required to produce velocity of efflux is comparatively small and is, in consequence, ignored. Where Box's formula is employed, the following general laws for pipe discharge obtain.

Varying the Diameter. According to the "Box" formula, the relative discharging power of pipes varies as the square root of the 5th power of the diameters. The following table gives the relative discharging power of pipes, in which a 1-in. diameter pipe is taken as unity.

Diameter		Diameter	
¼ in.	0·03	1½ in.	2·76
⅜ in.	0·09	2 in.	5·66
½ in.	0·18	2½ in.	9·88
¾ in.	0·49	3 in.	15·59
1 in.	1·00	4 in.	32·00
1¼ in.	1·75		

Example.—A 1¼-in. diameter pipe is calculated to discharge 15 g.p.m. What would be the discharge if the diameter is increased to 1½ in.?

$$\text{Answer} = 15 \times \frac{2{\cdot}76}{1{\cdot}75} = 24 \text{ gallons approximately.}$$

Conversely, a 1½-in. diameter pipe is calculated to discharge 24 g.p.m. what would be the discharge if the diameter is reduced to 1¼ in.?

$$\text{Answer} = 24 \times \frac{1{\cdot}75}{2{\cdot}76} = 15 \text{ gallons.}$$

Varying the Pressure Head. Where the diameter and length of pipe remain constant, the discharge varies as the square root of the head.

Example.—Suppose that for a head of 4 ft. the discharge from a given pipe is 10 g.p.m. If for the same diameter and length of pipe, the head is increased to 16 ft., the discharge would be

$$G_1 = G \times \sqrt{\frac{h_1}{h}}$$

Where
G_1 = discharge under new condition of head in g.p.m.
G = discharge under original condition of head in g.p.m.
h_1 = the new head in feet.
h = the original head in feet.

Applied to the example, this gives:

$$G_1 = 10 \times \sqrt{\frac{16}{4}}$$
$$= 10 \times \sqrt{4}$$
$$= 10 \times 2$$
$$= 20 \text{ g.p.m.}$$

Where for a given diameter the L/H value is constant, the discharge is unaltered.

Example.—For a 1½-in. diameter pipe, 40 ft. long, head 10 ft., the L/H value is $40 \div 10 = 4$, for which Table I gives a discharge of 37 g.p.m.

For a pipe 100 ft. long, head 25 ft., the L/H value is $100 \div 25 = 4$, for which the table gives a discharge of 37 g.p.m., as in the previous example.

Varying the Length. Where the diameter and head remain the same, and the length only is altered, the discharge varies as the square root of the length.

TABLE I. Determining Discharge of Water in Gallons per Minute

According to the Formula of Thomas Box

Compiled by W. E. Fretwell, F.R.San.I., M.I.Mech.E., P.P.I.H.V.E.

Value of length over head $\frac{L}{H}$	Diameter of pipe									
	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.
·2	10·68	29·4	60·5	105·7	166·2	341·4	596·7	938·8	1377·0	1923·0
·4	7·54	20·8	42·8	74·8	117·6	241·4	422·0	664·0	974·0	1360·0
·6	6·1	16·8	34·9	60·9	95·9	197·0	344·2	591·6	795·0	1109·0
·8	5·32	14·7	30·25	52·8	83·1	170·8	298·3	470·0	689·0	961·0
1·0	4·77	13·1	27·0	47·0	74·0	152·7	268·0	420·0	616·0	860·0
1·2	4·35	12·0	24·6	43·2	68·0	139·4	243·0	384·0	564·0	790·0
1·4	4·03	11·1	22·8	40·0	63·0	129·0	225·0	355·0	520·0	730·0
1·6	3·77	10·4	21·38	37·4	58·8	120·7	211·0	332·0	487·0	680·0
1·8	3·55	9·8	20·16	35·2	55·5	113·9	198·0	313·0	460·0	643·0
2·0	3·37	9·3	19·1	33·4	52·6	108·0	188·6	296·0	436·0	610·0
2·5	3·02	8·3	17·1	29·8	47·0	96·6	168·6	256·0	391·0	546·0
3·0	2·75	7·6	15·6	27·2	43·0	88·1	154·0	243·0	357·0	499·0
4·0	2·38	6·6	13·5	23·6	37·0	76·3	134·0	210·0	310·0	432·0
5·0	2·14	5·9	12·0	21·2	33·0	68·3	118·0	188·0	276·0	385·0
6·0	1·95	5·4	11·0	19·3	31·0	62·3	108·0	173·0	252·0	350·0
7·0	1·8	5·0	10·2	17·8	28·0	57·7	101·0	159·0	233·0	326·0
8·0	1·69	4·6	9·5	16·7	26·4	54·0	94·0	148·0	218·0	304·0
9·0	1·59	4·4	9·0	15·7	25·0	51·9	89·0	140·0	205·0	288·0
10·0	1·51	4·16	8·5	15·0	23·5	48·0	84·0	133·0	195·0	270·0
11·0	1·43	4·0	8·15	14·2	22·4	46·0	81·0	126·0	186·0	260·0
12·0	1·38	3·96	8·0	13·62	21·5	44·1	77·0	122·0	178·0	249·0
13·0	1·34	3·65	7·5	13·1	20·6	42·0	74·0	116·0	170·0	240·0
14·0	1·27	3·5	7·2	12·6	20·0	40·6	71·0	113·0	165·0	230·0
15·0	1·23	3·4	7·0	12·2	19·2	39·4	69·0	109·0	160·0	223·0
16·0	1·2	3·3	6·7	11·8	18·6	38·0	66·0	105·0	155·0	216·0
17·0	1·16	3·18	6·6	11·4	18·0	37·0	64·6	102·0	150·0	210·0
18·0	1·12	3·1	6·37	11·1	17·6	36·0	63·0	99·0	145·0	203·0
19·0	1·1	3·05	6·2	10·75	17·1	35·0	61·2	96·0	141·0	198·0
20·0	1·07	2·95	6·05	10·5	16·7	34·1	59·7	94·0	138·0	194·0
22·0	1·02	2·8	5·75	10·05	15·9	32·5	57·0	89·5	133·0	184·0
24·0	0·975	2·7	5·5	9·65	15·5	31·0	54·0	86·5	126·0	175·0
26·0	0·947	2·58	5·3	9·26	14·6	29·7	52·3	82·0	120·0	170·0
28·0	0·9	2·5	5·1	8·9	14·0	28·8	50·5	79·5	116·0	163·0
30·0	0·87	2·4	4·95	8·6	13·6	[illegible]7·8	48·8	77·0	113·0	158·0
32·0	0·84	2·32	4·76	8·3	13·2	[illegible]	47·4	74·3	109·0	154·0
34·0	0·82	2·24	4·63	8·06	12·7	[illegible]	46·0	72·0	106·0	147·0
36·0	0·79	2·18	4·5	7·84	12·3	2[illegible]5	45·6	70·0	103·0	143·0
38·0	0·775	2·12	4·37	7·63	12·0	24·8	43·5	68·0	100·0	140·0
40·0	0·75	2·08	4·25	7·5	11·75	24·0	42·0	66·5	97·5	135·0
45·0	0·712	1·96	4·03	7·05	11·12	22·76	39·8	62·6	92·0	128·0
50·0	0·675	1·86	3·82	6·68	10·5	21·6	37·7	59·5	87·5	121·0
55·0	0·635	1·77	3·64	6·34	9·98	20·6	36·2	56·6	83·0	116·0
60·0	0·612	1·7	3·5	6·1	9·6	19·7	34·5	54·5	80·0	111·0
70·0	0·57	1·56	3·25	5·63	8·85	18·2	32·0	50·0	73·6	102·0
80·0	0·53	1·47	3·025	5·25	8·35	17·0	29·8	47·0	69·0	97·0
90·0	0·505	1·38	2·84	4·95	7·8	16·2	28·2	44·2	65·0	91·0
100·0	0·477	1·31	2·7	4·7	7·4	15·2	26·8	42·0	61·6	86·0
125·0	0·427	1·17	2·41	4·2	6·6	13·6	24·0	37·5	55·0	77·0
150·0	0·348	1·07	2·2	3·83	6·05	12·5	21·8	34·2	50·3	70·0
200·0	0·337	0·93	1·91	3·34	5·26	10·75	18·86	29·6	43·6	61·0
250·0	0·302	0·83	1·71	2·98	4·7	9·64	16·86	25·6	39·1	54·6
300·0	0·276	0·76	1·56	[illegible]	4·3	8·82	15·4	24·3	35·7	50·0
350·0	0·255	0·7	1·44	2·5	3·95	8·16	14·3	22·4	33·0	46·0
400·0	0·238	0·66	1·35	2·36	3·7	7·6	13·4	21·0	31·0	43·2
450·0	0·226	0·62	1·27	2·22	3·5	7·2	12·6	19·8	29·0	40·5
500·0	0·214	0·59	1·2	2·12	3·3	6·8	11·8	18·8	27·6	38·5
550·0	0·207	0·558	1·15	2·0	3·16	6·5	11·4	17·8	26·2	36·6
600·0	0·195	0·54	1·1	1·93	3·1	6·2	10·8	17·3	25·2	35·0
700·0	0·18	0·5	1·02	1·78	2·8	5·76	10·1	15·9	23·3	32·6
800·0	0·1687	0·456	0·95	1·67	2·64	5·4	9·4	14·8	21·8	30·4
900·0	0·159	0·44	0·90	1·57	2·5	5·1	8·9	14·0	20·5	28·8
1000·0	0·151	0·416	0·85	1·5	2·35	4·8	8·4	13·3	19·5	27·0

Resistance of fittings to be taken into consideration in length value.

TABLE II—Diameter of Pipe

Diameter of pipe in ins.	½	¾	1	1¼	1½	2	2½	3	4
Equivalent length in ft. for one resistance	1.0	2.0	2.5	3.5	4.5	6.0	7.5	10.0	14.5

Example.—Suppose that for a given head the discharge from given pipe, 16 ft. long, is 10 g.p.m. If the length of pipe is increased to 64 ft., the head and diameter remaining the same as before, the discharge would be

$$G_1 = G \times \sqrt{\frac{L}{L_1}}$$

Where
G_1 = discharge under new condition in g.p.m.
G = discharge under original condition in g.p.m.
L_1 = the new length in feet.
L = the original length in feet.
Applied to the example, this gives:

$$G_1 = 10 \times \sqrt{\frac{16}{64}}$$
$$= 10 \times \sqrt{\tfrac{1}{4}}$$
$$= 10 \times \tfrac{1}{2}$$
$$= 5 \text{ g.p.m.}$$

If these examples are checked with Table I, they will be found to agree.

Resistance of Pipe Fittings. Every fitting, valve or connexion causing a change in the direction of flow tends to set up turbulence and to resist the flow of water. The more abrupt the change of direction, the greater the resistance. A bend having a radius of not less than five times the diameter, and without constriction of the bore, is generally assumed to offer no more resistance than a pipe of the same length.

The resistance of fittings, valves and other obstructions is in this section indicated by the letter *r*. The resistance to flow of water through pipe-fittings, valves, and other obstructions, is generally referred to in terms of the resistance of a square elbow, the resistance of which is taken as 1.

The actual resistance to flow through fittings is more or less indeterminate. The resistance ratios for commonly used pipe-fittings, etc., are shown in Fig. 2. These ratios are rather higher than those commonly employed so as to allow for incrustation. The resistance of pipe fittings is frequently expressed in terms of the equivalent length of pipe of the same diameter offering the same resistance to the flow of water. For the purpose of this section, the equivalent length of straight pipe in feet for a unit resistance, $r = 1$ may be taken as shown in Table II.

Example.—Calculate in terms of straight piping the resistance to the flow of water through two 2-in. elbows and one 2-in. globe valve.

Referring to Fig. 2 the resistance ratio (r) for an elbow is 1 and that of a globe valve is 4.

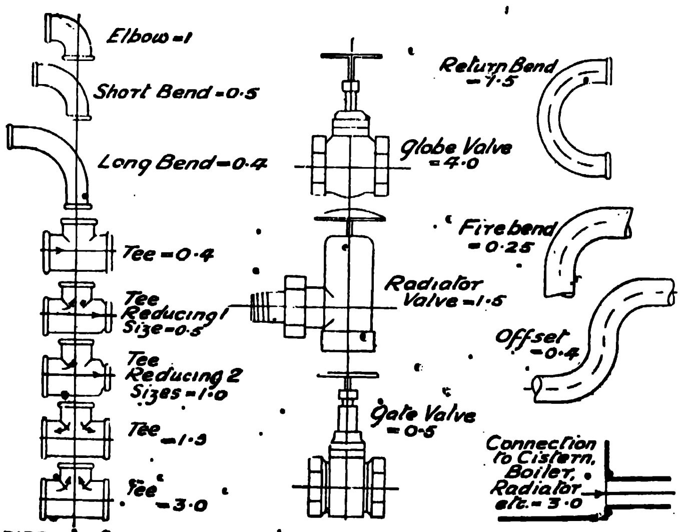
The total of the resistance ratios is therefore

$$(2 \times 1) + (1 \times 4) = 6.$$

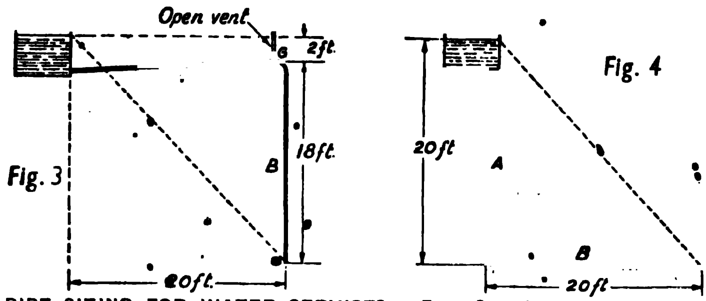
The equivalent length of pipe in feet for one resistance on a 2-in. pipe is 6·0, as shown in Table II. The length of straight piping equivalent in resistance to two 2-in. elbows and one 2-in. globe valve is therefore $6 \times 6{\cdot}0 = 36$ ft.

The discharge from a pipe is influenced by the arrangement of the pipe system. In Fig. 3 the outflow end of pipe A rises above the dotted sloping line. Assuming pipes A and B to be fully charged with water, the level of that in the gauge tube G cannot fall below the top of pipe A.

The head of water above pipe A is 2 ft. Pipe A is assumed to be 20 ft. long and pipe B 18 ft. long. With the arrangement shown in Fig. 3, it is necessary first to calculate the required diameter for pipe A having a head of 2 ft. for the



PIPE SIZING. Fig. 2. Resistance ratios for commonly used pipe fittings, allowance being made for incrustation (see text above).



PIPE SIZING FOR WATER SERVICES. Figs. 3 and 4, effect on pipe discharge of arrangement of pipe system: (left) 1½ in. diam. horizontal pipe and 1 in. drop pipe required for 20 g.p.m. discharge; (right) 1 in. diam. pipe required for same discharge.

line. Where this occurs the length of the pipes may be added together. In Fig. 4 the combined length of the pipes A and B is 38 ft. For a pipe 38 ft. long and a head of 20 ft., the *L/H* value is 1·9. For an *L/H* value of 1·9, Table I gives the discharge from a 1-in. diameter pipe as appropriate discharge. Pipe A is 20 feet long and the head available is 2 ft. The *L/H* value is, therefore, 20 ÷ 2 = 10. For an *L/H* value of 10 and an assumed discharge of 20 g.p.m., a 1½-in. diameter pipe is required.

Pipe B is 18 feet long, and the head available is 18 ft., the *L/H* value being 18 ÷ 18 = 1. For an *L/H* value of 1 and a flow of 20 g.p.m. a 1-in. diameter pipe is required. In the arrangement shown in Fig. 3, a drop pipe 1-in. diameter will carry the whole of the water delivered by the 1½-in. horizontal pipe.

Fig. 4 shows an alternative pipe system in which the whole is below the dotted between 19·1 and 20·16 g.p.m. With the alternative arrangement shown in Fig. 4, a 1-in. diameter pipe will just about meet the required discharge of 20 g.p.m.

Chart. For examples giving the practical application of pipe sizing principles *see* the Chart *facing page* 790.

In conclusion, it may be once again emphasized that the fundamental principle involved in "pipe sizing" is that the pipes must be of such a diameter as to ensure that the calculated frictional resistance of the system does not exceed the available head for the required outflow of water.

PIPE SIZING: (2) FOR GAS

By J. W. Cowan, A.M.I.H.V.E.

Explaining the principles of pipe sizing for gas, and the correct use of formulae. A Table derived from Lacey's formula is printed in page 368 ; another is here given for sizing service pipes, pressure drop being 0·1 in. w.g. See Estimating: (4) for Gas Fitter's Work Gas Fitting

In practice, the determination of the sizes of gas pipes for specific duties has been reduced to the use of tables and charts built upon the results of experimental investigation into this branch of hydraulics ; but the correct use of these summarized values necessitates an understanding of the basic formulae from which the tabulated quantities have been derived. One of the earliest of these is Pole's formula, according to which :

$$Q=1350\sqrt{\frac{HD^5}{SL}} \text{ or, } Q=1350D^2\sqrt{\frac{HD}{SL}}$$

when Q = Quantity of gas discharged in cu. ft. per hour.
H = Total frictional loss of pressure in inches water gauge.
D = Diameter of pipe in inches.
S = Specific gravity (Sp.G.) of gas relative to air.
L = Gross length of pipe in yds. including "equivalent length" additions for fittings.

Assuming a specific gravity of 0·5 and a permissible friction loss of 0·3 in w.g., it may be calculated that 60 ft. (20 yards) of 2-in. pipe would pass 1,323 cu. ft. of gas per hour, and that this would be increased to 1,707 cu. ft. for a pressure loss of 0·5 in. Most of the earlier pipe sizing tables for gas were derived from such calculations.

Later investigation led Mr. Stephen Lacey to give special consideration to the coefficient of friction and to the actual rather than the nominal bore sizes of pipes; modern tables and charts are normally based upon the results of his work.

Table I, page 368, has been derived from Lacey's formula (Trans. Inst. Gas Engrs., 1923), according to which:

$$Q = 188\sqrt{\frac{HD^5}{\mu SL}}$$

when μ = Coefficient of friction, L = Gross length in feet, and other values are as above.

TABLE I.—Table of Discharge for Straight Horizontal Pipes

With 0·1 in. differential pressure for gas of density 0·5 relative to air.

(Cu. ft. per hour.)

By S. Lacey, B.Sc.

Size of pipe in inches (nominal bore)	Length of Pipe in Feet 10	20	30	40	50	60	70	80	90	100	150	200	250	300
⅛	3													
¼	14	7												
⅜	33	18	12											
½	72	40	38	29	23									
¾	130	88	70	60	52	47	40							
1	240	165	130	110	98	89	81	75	71					
1¼	—	340	270	235	210	190	170	160	150	140	110	96		
1½	—	530	420	360	320	290	260	240	230	215	170	150	130	113
2	—	—	890	770	680	620	560	520	490	460	370	310	280	250
3	—	—	—	2240	1980	1800	1630	1510	1420	1340	1070	900	795	710

The μ (or "mu") value is a variable somewhat beyond the scope of these notes, but if 0·0070 is taken as the coefficient for 3-in. pipe and a 0·3 in. pressure drop, the calculated result will be found to agree closely with the tabulated values. The earlier formula gives somewhat higher results by reason of the omission of the friction figure: viz., 3,645 cu. ft. per hour for 60 ft. of 3-in. pipe and 0·3 in. w.g., against the tabulated figure of 3,365 cu. ft.

It is difficult to give a list of friction coefficients to enable Lacey's formula to be used for calculations beyond the scope of the Table on page 368 because the values are extremely variable, being a function of

$\frac{WVD}{v}$ when W = Density, D = Diameter, V = Velocity, and v = Coefficient of viscosity.

Table I (above), will be found of assistance in sizing service pipes, across which the usual pressure drop is only 0.1 in. w.g.

It should be noted that the standard figure of 0·5 specific gravity has been adopted throughout these calculations, and in the table on page 368. The volume of gas discharged varies inversely as the square root of the specific gravity for the same pressure loss, and the tabulated quantities of both tables would be subject to correction as under for gas of specific gravity of other than 0·5, vide Table II.

$$\text{Tabulated discharge} \times \sqrt{\frac{0{\cdot}5}{\text{Sp.G. of gas, Table II}}}$$

TABLE II.—Calorific Value and Specific Gravity of Coal Gas.

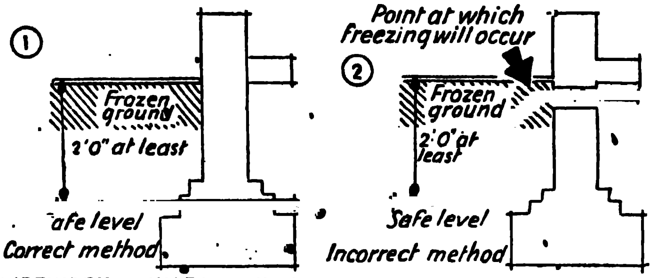
C.V.	Sp.G.
350	0·60
400	0·58
500	0·50
560	0·43

PIPEWORK: (1) WATER PIPES IN LEAD

By E. J. Tillier, A.R.San.I., R.P.

In this article the protection and fixing of lead piping are dealt with. Modern fixing methods are described and illustrated. See *also* Frost ; Lagging ; *and* for the manufacture, weights and description of lead pipes see Pipe : (1) Lead. For the jointing of lead pipes see Joints : (1) Wiped Joints to Lead Pipes. An article on Pipework in Iron, Steel and Copper follows the present one.

One of the chief advantages in the use of lead pipes in building work is the fact that, during installation, relatively long lengths can be used, resulting in a reduction of the number of joints. In addition, the ease with which lead piping can be bent to conform to any change in direction saves time and labour when compared with pipes made of metals having less malleability. As lead pipe is insufficiently rigid to support itself in any appreciable length, one of the most important points to consider when installing this pipe is the fixing methods for horizontal and vertical runs. Unfortunately this did not receive sufficient attention in the past, and resulted in numerous failures in installations, not because of the inferior quality of the metal, but due to lack of adequate support, which resulted in undue stress and consequent fracture. Modern fixing methods are the result of the experience gained through these past failures, and a properly supported and protected lead piping installation has an almost indefinite life.



PIPEWORK: WATER PIPES IN LEAD. Figs. 1 and 2. Frost protection for pipe at entry to house: (1) pipe safely laid below level to which ground is likely to freeze; (2) rising pipe, subject to freezing.

A. PROTECTION OF PIPING

Pipes in Trenches. Service piping in trenches requires protection from the action of certain soils which are liable to cause external corrosion. One of the most deleterious of these is "made up" ground containing waste matter and ashes, and a lead pipe buried in this soil has a comparatively short life. In good practice a bitumen lined trench is made for the pipe or pipes, and is covered with tiles, stone slabs, or hardwood. Another method (which is cheaper where cost has to be considered), is to ram the bottom of the trench so as to make a solid bed, the pipe being bound with canvas, and afterwards coated with bitumen.

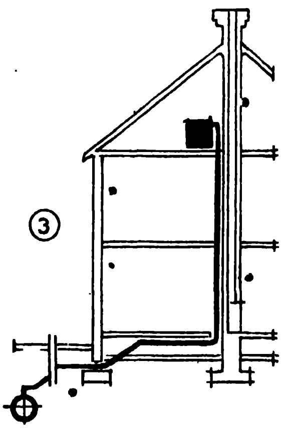


Fig. 3. Rising main and cistern protected from frost: pipe and cistern installed against inside wall adjacent to chimney.

In clay and other soils a bed and covering of sand is usually sufficient to protect the pipe, both from chemical action and from movement due to the varying moisture content of the ground.

Where pipes have to negotiate concrete roads and paths, it is preferable if possible to run underneath the concrete bed, to allow free movement of the pipe. This is important where there is considerable vibration. In cases where this method cannot be adopted it is advisable to form a conduit of earthenware pipes; this, in addition to allowing free movement, facilitates the withdrawal of the pipe should this be necessary.

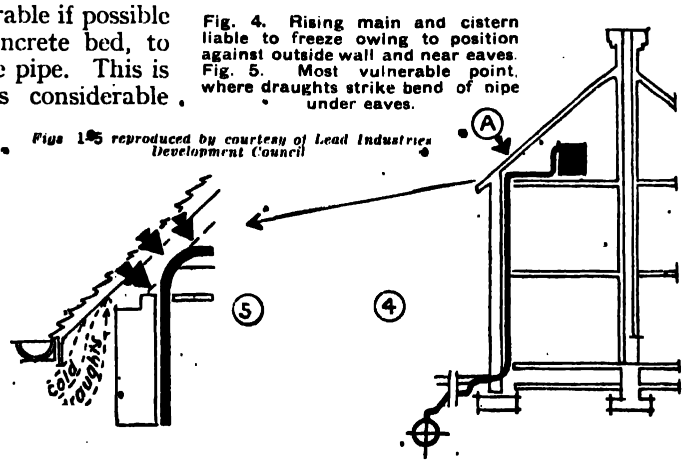
It is bad practice to lay unprotected lead pipes in concrete or cement screeds. At least a protective covering of thick building paper or felt should be provided.

Frost Protection. It is necessary to excavate pipe trenches of sufficient depth to prevent freezing in severe weather; 2 ft. is normally considered to afford protection, but a number of water supply undertakings insist on a depth of 2 ft. 6 in. In cases where the footings of a building are shallow, a common mistake sometimes made is for the pipe to rise from a depth of from 2 ft. to 2 ft. 6 in. to enter the external wall a few inches below ground level. This is done, no doubt, to save cutting through the extra thickness of the footings; but can be avoided by inserting an earthenware pipe at the desired depth during building operations, and so forming a conduit through which the lead pipe can afterwards be threaded when the internal services are commenced. *See* Figs. 1 and 2.

The rising main entering the building should be taken to a suitable internal wall before rising to the storage tank situated in the roof space; this lessens considerably the risk of freezing. A good arrangement is shown by Fig. 3, where the pipe is on a wall warmed by a flue. Where open eaves allow cold currents of air to enter

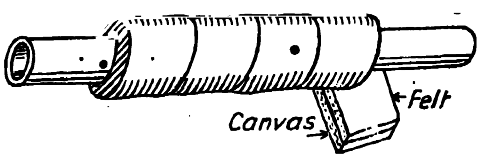
Fig. 4. Rising main and cistern liable to freeze owing to position against outside wall and near eaves. Fig. 5. Most vulnerable point, where draughts strike bend of pipe under eaves.

Figs 1-5 reproduced by courtesy of Lead Industries Development Council



the roof space, and service pipes are fixed on external walls, trouble is almost certain to occur at a point where the pipe comes through the ceiling and is bent to run horizontally towards the tank. *See* Figs. 4 and 5.

Canvas-Backed Felt. Where pipes are fixed on the surface in exposed internal positions, various forms of insulation are available. The commonest type is canvas-backed felt (*see* Fig. 6). It is



PIPEWORK : WATER PIPES IN LEAD. Fig. 6. Canvas-backed felt, used for lagging waterpipes in exposed internal positions.

obtainable in rolls 24 ft. long by 4 in. wide, and is wound spiral fashion on to the pipe; the canvas is slightly wider on one edge than the felt, to allow for an overlap at the joints. In addition, the material is held in position with twine or, in better class work, with copper wire. This is wound in the opposite direction, to prevent the felt from becoming loosened.

Canvas-Backed Asbestos Spiral Strip. Another form of protection similar to that already described, and is fixed in a similar manner. The efficiency of this as an insulating material is much higher than felt. For general purposes it is obtainable in rolls of 18 ft. by 3 in. wide and ½ in. nominal thickness.

Glass Wool. An efficient insulator, fixed in much the same way as the other types described; it is supplied in long rolls, and is wound round the pipes and covered with canvas binding.

Slag Wool. Is mostly used for protecting pipes run in chases and ducts, also for protecting cisterns by introducing this material between the boarded casings and the storage tanks. Other information on insulation, both for internal and external situations, is given under the heading Lagging.

B. FIXING METHODS FOR LEAD PIPES

Too much importance cannot be placed on the need for adequate fixing of lead service and distribution pipes, particularly where this metal is used for hot water systems.

Horizontal Pipes. Pipes fixed on the surface with pipe hooks, lead tacks, or clips, should be continuously supported on wood battens. This method, in addition to providing a reliable means of preventing the pipe from sagging, also makes much easier the work of straightening the lead piping during installation.

Pipes under Wood Floors should, when running in the same direction as the joists, be supported by wood fillets fixed to same, and the pipe be held in position with clips or lead tacks. Where small diameter pipes run in crosswise direction to the joists, holes may be drilled in these latter through which piping may be reeved or threaded. It is essential, however, that each hole should be drilled a uniform distance from the top of joists, except where a gradient is necessary.

Pipes under Ground Floors of wood construction, and which are supported at intervals by sleeper walls, should preferably run on the flat concrete foundations. Attention is drawn to the fact that frost protection is generally necessary, as cold air currents can enter through the air-bricks usually provided in these situations.

Pipes under Solid Floors should be run in chases or ducts having removable covers of similar material; in cases where pipes are laid in solid floors, a felt binding, paper wrapping, or a coating of thick bitumastic paint is desirable.

Pipes in Roof Space where the ceiling joists are not boarded need some form of support; a lay board is usually fixed with a slight upward incline toward the cistern, or storage tank. Tinned pipe clips are generally used for fixing the pipes on these boards.

Vertical Pipes. Where run on the surface, these in good-class work are usually fixed with lead tacks " wiped " on to the lead pipe at intervals of 3 ft. and screwed to the wall. The use of pipe hooks and clips is resorted to in other circumstances, and these are fixed at intervals of not more than 30 ins.

Piping in Chases or Recesses. For either horizontal or vertical runs the piping is preferably fixed by lead tacks or clips to a back-board provided. In other cases, where pipe hooks are used, a strip of sheet lead is inserted between the hook and the lead pipe to prevent damage.

The chases are usually covered by moulded casings, and are fixed at intervals

with screws to allow of easy access for inspection.

Piping bedded in cement renderings behind tiles, and other impervious materials, such as are now used in bathrooms, kitchens, etc., must be allowed to move freely in the chases provided; and efficient protection is necessary against the free alkali that occurs during the setting reactions in cement. Light building paper is generally used for this purpose.

There are certain detrimental features that characterize this method of concealing piping: (1) access to the pipe is not possible unless the tiling is removed; (2) where fixed on the inside of exposed external walls, the paper wrapping forms no effective protection against damage by freezing. It is most desirable in these circumstances that a chase be provided of sufficient dimensions to allow for efficient insulation.

PIPEWORK: (2) IRON, STEEL AND COPPER TUBE

By J. W. Cowan, A.M.I.H.V.E.

This article is complementary to those on Pipe and Pipe Fittings, and on Pipe Bending. Additional information is here given, mainly on erection and installation of pipework. The sections are: A, Erection of piping; B, Making connexions. *See also* Screw Cutting. For methods of specifying pipe fittings see Chart facing page 791.

In these notes it is assumed that the material of the pipe—steel or copper—has been chosen with due regard to the line fluid, and that the pipe sizes and general layout have been decided. (Pipe sizing is the subject of specific articles earlier in this work. Jointing and bending are dealt with under Pipes and Pipe Bending respectively.)

Steel Pipe. This is also known as (wrought) "iron" pipe, but unless in exceptional circumstances, ordinary screwed pipe is almost invariably of mild steel. When delivered at site in single lengths or in bundles, depending on size, the ends are normally wrapped in hessian bags, which protect the threads and guard against chokage during transit. When the bags have been removed, the general untidiness of a building site makes chokage a not unlikely contingency, and because of a danger to valves from a plug of sand or earth within a pipe, it is necessary to examine each length before placing it in position. It is only necessary to look through large pipes, and it is customary to blow through smaller ones. Water from a hose is sometimes run through to ensure freedom from chokage; this can be done with advantage in all sizes after forge-bending, to remove the scale which must have formed during heating, and which might later loosen and find lodgment in a valve.

Copper Pipe. Light gauge copper tube is normally delivered in boxes about 20 ft. long; the smaller tubes are frequently packed inside larger ones, from which they should be withdrawn for checking and stacking at site. It is important that this pipe be stored carefully, to avoid bruising and damage which would make jointing difficult and cause unnecessary wastage. The following notes, with the exception of those on screwing, apply equally to copper and steel pipe lines.

A. ERECTION OF PIPING

Two methods of erecting pipework are in general use, and both require that holes for pipes be left through walls and floors at the time of building; this is usually done by building-in short lengths of timber about twice the size of the pipe for which the hole is required. In large buildings this calls for good supervision and some forethought, but it is much better practice than cutting holes through "green" brickwork and concrete.

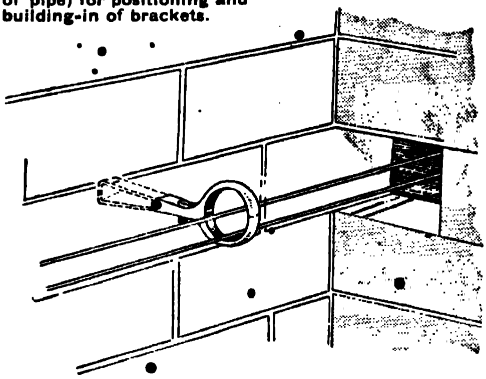
Two Methods of Erection. In the first method double chalk lines are fitted through the holes in walls and floors between chisel-like spikes about 12 in. long, and are so alined and spaced as to mark the exact bottom- and back-centre lines of each pipe (as shown in Fig. 1 p. 796). The brackets are then built-in, or suspended from girders, etc., so that when the lines have been removed the pipes need only be cut and screwed to size and hoisted into position. This is the general practice in first-class work, but it requires more experienced supervision than is usually available in keenly competitive work.

In the second method, holes for brackets are marked and cut, and the pipes are fitted into their approximate positions,

and supported temporarily on spikes driven into brick joints, and by wire slings. When the pipe levels have been corrected and checked, branch connexions are made and the pipe brackets are then fitted round the pipes and built into position.

The first method is both better and quicker, and is always to be preferred for

PIPEWORK : IRON, STEEL, & COPPER. Fig. 1. Method of erecting pipework : double chalked string lines in place (marking bottom and back-centre lines of pipe) for positioning and building-in of brackets.



welded pipework. As much of the welding as possible is done at floor level, and the long lengths which are finally hoisted into position cannot easily be carried on spikes during the process of packing up into alinement which precedes the fitting of the brackets in the second method.

Alinement. The alinement of pipes for different line fluids is discussed under appropriate headings (*i.e.* Gas Fitting; Heating; Hot Water Supply). Generally pipes carrying liquids should rise slightly in the direction of flow, and should be taken over rather than under an obstruction to the straight run; where this is impracticable, the highest point of each section must be separately vented by means of either a pipe or valve to prevent air-lock. In contrast to this, pipes conveying air, gas and steam, etc., are required to fall in the direction of flow. These pipes are better taken under an obstruction rather than over it, and must be drained at the lowest point of each rise above the general gradient.

The normal alinement of horizontal pipes varies from ½ in. to 1 in. in 10 ft., and a spirit level alone is of little use in maintaining such a gradient. A "stepped straight-edge" as shown in Fig. 2 may be used with advantage, and should be as long as possible up to about 10 ft. The required slope determines the thickness of the step in relation to the length, and each section of pipe is alined so that the spirit level shows the top of the straight-edge to be dead level. The stepped straight-edge is used in the second method of erection, and is seldom shorter than 5 ft.; use spirit levels from 2 ft. to 3 ft. long with temporary steps for shorter sections.

In the alinement of the chalk lines in the first method of erection, light aluminium-cased "line levels" (spirit levels) are used. These are fitted with a screwed adjustment at one end in place of the step on the straight-edge, and can be hooked on to a taut line without sagging.

Reducing Fittings. The correct use of these fittings—shown in Figs. 10 and 11 of the article Pipe (4) —is a point of some importance in the alinement of pipework. The eccentric pattern is always to be preferred to the plain concentric type on both horizontal and vertical pipes, whatever the line fluid. On vertical pipes the flat side is used to maintain an equal spacing from the wall. On horizontal pipes they are used flat side upwards for liquid line fluids to facilitate venting; for air, gas and steam pipes (including condense pipes) the flat side is turned downwards to assist draining of moisture.

Spacing of Supports. Pipe supports should be spaced to prevent sagging as well as to bear the weight of the pipes (Table I).

In supporting vertical pipes it is essential that a fitting bears directly upon

TABLE I—**Maximum Spacing, Horizontal Pipes**

Nominal Bore Diameter	Distance between Supports	
	Steel and Heavy Copper	Light Gauge Copper
½ in. (and smaller)	6 ft.	4 ft.
¾ and 1 in.	8 ft.	6 ft.
1¼ in.	9 ft.	8 ft.
1½ and 2 in.	10 ft.	9 ft.
2½ and 3 in.	12 ft.	10 ft.
4 in.	13 ft.	10 ft.

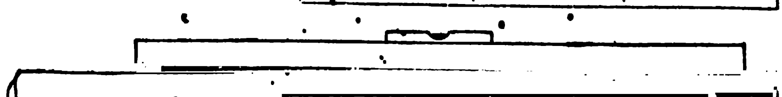
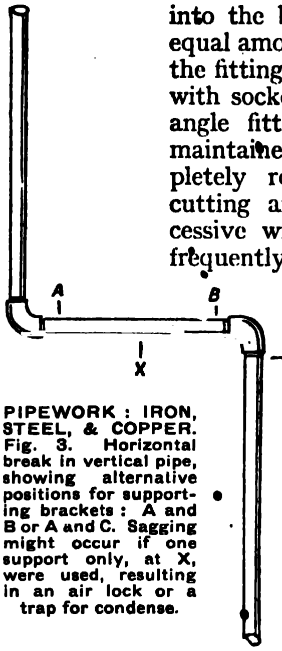


Fig. 2. Stepped straight-edge as used in alinement of pipework by the second method described above. The thickness of the step in relation to length is determined by the required slope.

each bracket; unless so fitted, a loose-grip pipe clip can only stay the pipe to a wall, and cannot bear any share of the weight. Supports are then fitted under the tees of branch connexions wherever possible: this is usually sufficient for copper pipes but, in the absence of tees, sockets would be provided on steel pipes to suit the brackets. Two supports should always be used on a horizontal break in a vertical pipe, however short it may be; these may be fitted either at A and B or at A and C in Fig. 3. The "riding" action and sagging that might result from the use of only one support at point X might in time cause either an air-lock at B or a trap for condense at A.



PIPEWORK: IRON, STEEL, & COPPER. Fig. 3. Horizontal break in vertical pipe, showing alternative positions for supporting brackets: A and B or A and C. Sagging might occur if one support only, at X, were used, resulting in an air lock or a trap for condense.

Spacing from Walls. To avoid dirt traps and to facilitate decoration and cleaning, pipes and pipe coverings are normally required to be from ¾ in. to 1 in. clear of finished wall surfaces. An allowance of ¾ in. for plaster requires that uncovered pipes be fitted from 1½ in. to 1¾ in. clear of rough brickwork; in addition to which due allowance must be made for any covering to be used. One inch extra would sometimes be sufficient, but sectional pipe covering, whether of an asbestos-magnesia compound, or of cellular construction as shown in Fig. 4, normally ranges from 1½ in. to 2 in. in wall thickness. Supports for copper pipes are usually of polished brass or copper: brackets of the type shown in Fig. 1 would be made of brass; and light distance clips (Fig. 5) are normally of heavy sheet copper.

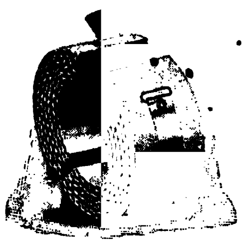


Fig. 4. Sectional pipe "air cell" insulation about 1½ in. to 2 in. in wall thickness, and normally fitted in 3-ft. lengths.
Ideal Boilers and Radiators, Ltd.

B. MAKING CONNEXIONS

In the screwing together of pipes and fittings the too-frequent use of a wrench can cause much unnecessary bruising and marking. When a pipe is held in a vice, a short length of pipe screwed hand-tight into the branch of a fitting provides an equal amount of leverage without marking the fitting. Where this cannot be used, as with sockets, bushes, lateral Y and other angle fittings, the first grip should be maintained and the wrench turned completely round the pipe to avoid the cutting and "chewing" action of successive wrench grips. These levers are frequently cut from galvanized pipe for cleanliness, and sometimes have a number of ⅜-in. holes drilled through the wall to prevent their being used for other purposes. A useful guide to the correct length of wrenches and levers is "12 times the pipe size" from a minimum of 10 in. That means an 18-in. wrench or lever for 1½-in. pipe, and 24 in. for 2-in. pipe; and adherence to this rule will generally be found to reduce the number of split fittings to be buried at site shortly before completion.

Screwing of Pipes. Notes on this operation are given under the heading Screw Cutting. *See also* Pipe: (6), page 769, *and under* Die Stock.

Thread Alinement. There are two ways in which a pipe thread may be out of true alinement. The first and most common is when the prominent parts of a thread have been bruised or damaged and do not lie at an angle of 55 deg. between adjacent slopes. This becomes apparent when a fitting cannot be screwed on to a pipe fully half-way by hand. The damaged threads may be corrected by screwing on the fitting as far as possible by hand and then tapping the fitting with a hammer: the vibration of the blow causes the good threads to straighten the damaged ones, and the fitting is then screwed on farther until another blow is required.

This operation is done without jointing paste, and the fitting must be removed and the pipe thread painted before the final connexion is made.

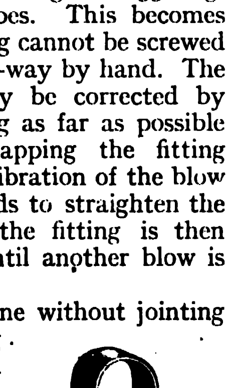
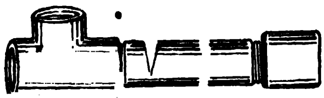


Fig. 5. Pressed copper distance clip for light gauge copper pipe, to ensure wall clearance.
Yorkshire Copper Works, Ltd.

The second fault, bad alinement of the tapping within a tee or other fitting, is not

uncommon among wrought iron pipe fittings, and in the screwed bosses of galvanized hot water cylinders. This is seen when a pipe has been screwed into a fitting or boss and is found to "kick" out of alinement from the defective fitting. Generally, such a fitting should be scrapped, but the fault is frequently corrected by making a saw-cut on the pipe about 1 in. behind the thread and about three-quarters way through the pipe, so that the cut will be opened as the pipe is pulled up (or down) into correct alinement. The cut is slightly exaggerated in Fig. 6. This is followed by tack-welding the cut in situ, and then by completely welding the opening when the pipe has been removed from the fitting.



PIPEWORK: IRON, STEEL, & COPPER. Fig. 6. Saw-cut (slightly exaggerated) made in pipe to correct bad alinement with fitting, due to faulty tapping of latter. Ready for tack-welding in situ.

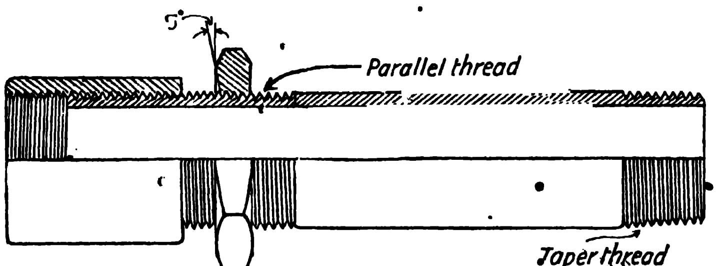


Fig. 7. Single longscrew or "connector," according to B.S.S. No. 788/1938; used in much the same way as a union.

The Longscrew. This fitting, known colloquially as a "connector," consists of a short length of pipe with a standard taper thread at one end, and a triple-length parallel thread carrying a backnut and socket at the other, as shown in Fig. 7. It is used for much the same purpose as a union, generally to connect or reconnect two sections of the same pipe line which have previously been fitted into position so that they cannot afterwards be turned without unscrewing elsewhere. The short thread is first screwed into a socket or other fitting on one of the ends to be connected, and the overall length of the whole fitting must be such that, when this has been done, the face of the longer thread will lie within ⅛ in. or so of the second pipe, as shown in Fig. 8. The socket of the longscrew is then run off the parallel thread and screwed to the adjacent short thread: when screwed home this socket will completely cover the short thread, and will be only half-way off the longscrew.

In order to make a pressure-tight joint between the other end of this socket and the parallel thread of the fitting some form of packing is necessary. Frequently hemp dressed in jointing paste is bound round the thread close to the socket, and driven into position by the recessed or "dished" face of the backnut when that fitting is screwed up wrench-tight against the socket. In better work a "grummet" or previously-made ring of dressed hemp, would be placed between socket and backnut before assembly, so that it would only need to be rolled up behind the socket and tightened by the backnut. When bound hemp is used, it is important that the direction of binding be clockwise from the back of the socket, so that the turning of the backnut will tighten and not loosen the turns of hemp.

It will be seen from Fig. 8 that one of the pipes to be connected must be moved out of alinement in order to fit a single-ended longscrew into the position shown in that illustration. Where the pipes are too rigid to admit of sufficient movement a double longscrew (as shown in Fig. 9) must be used; the overall length of such a fitting would be about ⅛ in. less than the distance "A," in Fig. 8. It may be noted that malleable iron sockets normally have a recessed face corresponding to the 5 deg. recess of the backnut

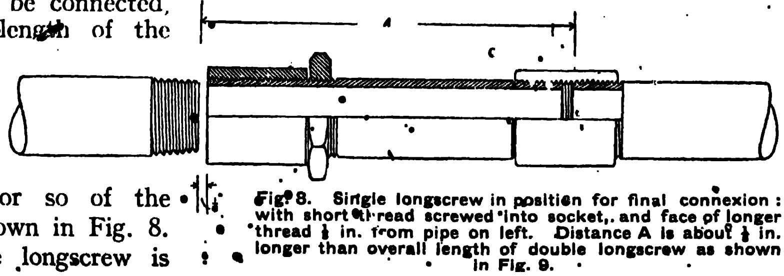
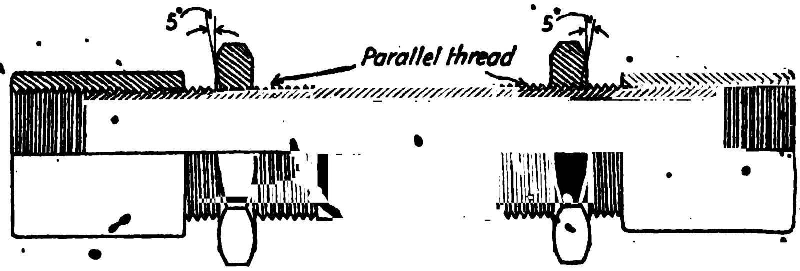


Fig. 8. Single longscrew in position for final connexion: with short thread screwed into socket, and face of longer thread ⅛ in. from pipe on left. Distance A is about ⅛ in. longer than overall length of double longscrew as shown in Fig. 9.



PIPEWORK : IRON, STEEL, & COPPER. Fig. 9. Double longscrew, employed where pipes are too rigid to permit use of single longscrew. Compare with Fig. 8, page 798.

in conjunction with which they provide better accommodation for a hemp grummet than the straight-faced mild steel sockets frequently used.

Connexions to Tanks. In competitive work longscrews are frequently fitted through previously cut holes in tank plates, but this is not good practice, for the reason that watertightness depends entirely on the hemp grummet. In good work, single or double flanges are invariably used. For a single connexion, as an outlet or overflow, a single flange would be bolted to the outside of the tank. For a double connexion, as when a supply pipe serves a ball valve inside a tank, double flanges are necessary, one outside and the other inside, for the separate connexion of pipe and valve. In very cheap work a ball valve is sometimes fixed through a tank plate by means of a brass backnut, so that the supply pipe may be connected to the screwed brass shank of the valve outside the tank ; this practice is to be deprecated except, perhaps, in w.c. cisterns where the lead connexion pipe would take any stress there might be.

Local authorities frequently specify the relative sizes and positions of tank supply and overflow pipes. In the absence of regulations to the contrary, a useful rule requires the overflow pipe to be two commercial sizes larger than the supply pipe, and stipulates that the centre of the ball valve connexion shall be at least 1 in. above the top of the overflow pipe. A much improved overflow connexion may be made by using double flanges and screwing a M & F elbow into the inside flange in order to provide a fullway outlet, as shown in Fig. 10.

Electrolysis : Copper & Galvanized Tanks. Accelerated corrosion of galvanized tank plates is sometimes brought about by the natural flow of static electricity because of the use of copper pipes in the same installation. The conditions under which this may occur should be clearly understood.

First, it is necessary that the water be sufficiently acid to have a discernibly corrosive action on copper ; and, secondly, that the direction of flow be from copper pipe into a galvanized tank or cylinder. In these circumstances the copper in solution in the water would hasten the breakdown of the galvanized plates, because both zinc and iron are electro-positive to copper and displace this metal from solution of its salts, the zinc and iron passing into solution.

Where the position is reversed and an active water flows only from galvanized work into copper, there is much less likelihood of trouble ; even then, however, it is not advisable to connect the copper outlet pipes directly to the tank, because of the risk of copper gaining access to the tank during absence of flow and setting up centres of corrosion near the points of connexion.

This may be prevented by fitting 12 inches or so of galvanized pipe between the tank and the copper pipe to ensure that whatever action there may be shall take place within the comparatively heavy-walled galvanized pipe. It should be noted that attempted "insulation" of the copper by means of rubber washers is useless, and can in no way retard such corrosion.

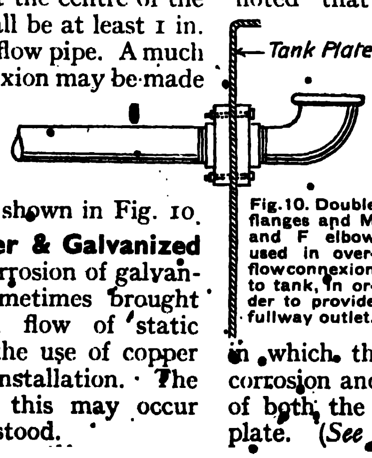


Fig. 10. Double flanges and M and F elbow used in overflow connexion to tank, in order to provide fullway outlet.

Because of this tendency of both zinc and iron to "electroplate" themselves on to copper, it is important in the case of acid waters that care be taken to exclude copper filings from galvanized work, in which they would set up centres of corrosion and would accelerate the wasting of both the zinc coating and the ferrous plate. (*See* Electrolysis.)

Identification of Pipework. British Standard 617 of 1942 details the standard method of marking service pipe for ease of identification in buildings other than chemical works. An explanatory summary is given. The complete Standard is issued at 2s. 6d. post free, by the British Standards Institution, 28, Victoria Street, London, S.W.1.

System of Identification

Each *service* shall be distinguished by a standard basic colour, as column 2 of Table I. The purposes of the different pipes within each *service* shall be indicated by the appropriate letters, as column 4 of Table II, painted in the contrasting colour shown in column 5.

Where different classes of one *service* are contained within a recess or wall chase, the access door of the chase shall be painted in the basic colour of the *service*, and provided with the several identification letters of the different pipes. In addition, if desired, the function of a control valve may be specially indicated.

Application

The pipes should preferably be painted in the standard basic colour throughout their length. Alternatively, sections of each pipe, not less than 12 in. in length, may be so painted adjacent to all branches, control points and junction boxes. If desired, one or more such sections of pipe may also be so painted in each compartment of the building through which the pipe passes.

The identification letters shall be painted on the pipe in a position adjacent to all branches, control points and junction boxes. Where the basic colour is painted only on sections of the pipe, the lettering shall be on the sections.

If desired, the name of the class of *service*, shown by initial letters in column 4 of Table II, may be painted in full. The words "High Voltage" and "Petrol" shall always be in full.

Where necessary, an arrow in the same contrasting colour as the lettering, indicating the direction of flow of fluids, may be added.

• All identification letters shall be so painted as to be plainly visible at the angle from which the pipes are most readily viewed.

Size of Lettering

Block letters shall be used of the following sizes:

On pipes 2 in. dia. and under .. .. $\frac{3}{4}$ in.
On pipes over 2 in. dia. .. .. $1\frac{1}{4}$ in.

The arrow, where used, should be of the following lengths:

On pipes 2 in. dia. and under .. .. 3 in.
On pipes over 2 in. dia. .. .. .. 6 in.

The standard colours shall be in accordance with the British Standard Schedule of Colours or Ready Mixed Paints (B.S. 381).

Note: Where a pipe carries a high temperature fluid, a suitable paint should be used.

TABLE I

SUMMARY OF COLOUR SCHEME

Service	Basic Colour	Contrasting Colour
Air	White	Black
Drainage	Black	White
Electricity	Orange	Various
Gas	Deep Cream	Black
Oil	Light Brown	White
Petrol	Light Brown	Red in black rectangle
Refrigeration	French Grey	Black
Steam	Crimson	Aluminium
Water, fresh, cold	Azure Blue	White
Water, fresh, hot	Sky Blue	Black
Water, central heating	Brilliant Green	White
Water, fire service	Signal Red	White
Water, sea (or salt)	Sea Green	Black

TABLE II. **IDENTIFICATION TABLE (abbreviated)**

Service	Basic Colours: Colour	B.S. No.	Identification Letters: Lettering	Contrasting Colour
AIR				
Vacuum	White	—	AV	Black
Compressed	"	—	AC	"
Ventilation Inlet	"	—	AI	"
Ventilation Extract	"	—	AE	"
NOTE: Pressure in lb. per sq. in. gauge should be indicated where necessary.				
DRAINAGE				
Soil	Black	—	DS	White
Waste	"	—	DW	"
Rain and Surface	"	—	DR	"
Vent	"	—	DV	"
STEAM				
Saturated	Crimson	40	SS	Aluminium
Superheated	"	40	SH	"
Exhaust	"	40	SE	"
Condense	"	40	SC	"
NOTE: Pressure in lb. per sq. in. gauge should be indicated where necessary.				
WATER				
Fresh Water, Cold:				
Town Main	Azure Blue	4	WCT	White
Well Main	"	4	WCW	"
Distributing	"	4	WCD	"
Distributing (softened)	"	4	WCS	"
Hydraulic Power	"	4	WCP	"
Fresh Water, Hot:				
Service	Sky Blue	1	WHS	Black
Vent	"	1	WHV	"
Cold Feed	"	1	WHF	"
Overflow	"	1	WHO	"

END OF VOLUME II